THE

POPULAR SCIENCE MONTHLY.

APRIL, 1878.

EVOLUTION OF CEREMONIAL GOVERNMENT.

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III. MUTILATIONS.

FACILITY of exposition will be gained by approaching indirectly the facts and conclusions here to be set forth.

As described by Burton, the ancient ceremony of infeftment in Scotland was completed thus: "He [superior's attorney] would stoop down, and, lifting a stone and a handful of earth, hand these over to the new vassal's attorney, thereby conferring upon him 'real, actual, and corporeal' possession of the fief." Among a distant, slightly-civilized people, a parallel form occurs. On selling his cultivated plot, a Khond, having invoked the village deity to bear witness to the sale, "then delivers a handful of soil to the purchaser." From cases where the transfer of lands for a consideration is thus expressed, we may pass to cases where lands are by a similar form surrendered to show political submission. When the Athenians applied to Persia for help against the Spartans, after the attack of Cleomenes, a confession of subordination was demanded in return for the protection asked; and the confession was made by sending earth and water. A like act has a like meaning in Feejee: "The *soro* with a basket of earth . . . is generally connected with war, and is presented by the weaker party, indicating the yielding up of their land to the conquerors." And similarly in India: When, some ten years ago, Tu-wên-hsin sent his "Panthay" mission to England, "they carried with them pieces of rock hewed from the four corners of the [Tali] mountain as the most formal expression of his desire to become feudatory to the British crown."

This giving of a part instead of the whole, where the whole cannot be mechanically handed over, may be called a symbolic ceremony;

though, even apart from any further interpretation, we may say that it approaches as nearly to actual transfer as the nature of the case permits. We are not, however, obliged to regard this ceremony as one artificially devised; but we may affiliate it upon a ceremony of a simpler kind which at once elucidates it, and is elucidated by it. I refer to giving up a part of the body as implying a surrender of the whole. In Feejee, tributaries approaching their masters were told by a messenger that "they must all cut off their *tobe* (locks of hair that are left like tails). . . . They all docked their tails." Still, it may be replied that this act, too, is a symbolic act—an act artificially devised rather than naturally derived. If we carry our inquiry a step back, however, we shall find a clew to its natural derivation.

First, let us remember the honor which accrues from accumulated trophies; so that, among the Shoshones, for instance, "he who takes the most scalps gains the most glory." Let us join with this Bancroft's statement respecting the treatment of prisoners by the Chichimecs, that "often were they scalped while yet alive, and the bloody trophy placed upon the heads of their tormentors." And now let us ask what will happen if the scalped enemy survives and is taken possession of by his captor. The captor preserves the scalp as an addition to his other trophies; the vanquished enemy becomes his slave; and he is shown to be a slave by the loss of his scalp. Here, then, are the beginnings of a custom that may become established when social conditions make it advantageous to keep conquered foes as servants instead of eating them. The conservative savage will change his custom as little as possible. While the new practice of enslaving the captured grows up, there will continue the old practice of cutting from their bodies such parts as serve for trophies without impairing their usefulness; and it will thereafter result that the marks left will be marks of subjugation. Gradually as the receipt of such marks becomes by use identified with bondage, not only will those taken in war be marked, but also those born to them; until at length the bearing of the mark shows subordination in general.

That submission to mutilation may eventually grow into the sealing of an agreement to be bondsmen, is shown us by Hebrew history: "Then Nahash the Ammonite came up, and encamped against Jabesh-gilead: and all the men of Jabesh said unto Nahash, Make a covenant with us, and we will serve thee. And Nahash the Ammonite answered them, On this condition will I make a covenant with you, that I may thrust out all your right eyes." They agreed to be subjects, and the mutilation (not in this case consented to, however) was to mark their subjection. And while mutilations thus serve, like the brands a farmer puts on his sheep, to show first private ownership, and afterward political ownership, they also serve as perpetual reminders of the ruler's power; so keeping alive the dread that brings obedience. This fact we see in the statement that when the second Basil deprived

fifteen thousand Bulgarian captives of sight, "the nation was awed by this terrible example."

Just adding that the bearing of a mutilation, thus becoming the mark of a subject race, survives as a token of submission when the trophy-taking which originated it has disappeared, let us now note the different kinds of mutilations, and the ways in which they severally enter into the three forms of control—political, religious, and social.

When the Araucanians on going to war send messengers summoning confederate tribes, these messengers carry certain arrows as their credentials; and, "if hostilities are actually commenced, the finger or (as Alçedo will have it) the hand of a slain enemy is joined to the arrows"—another instance added to those already given, in which hands cut off are brought home to show victory.

We have proof that in some cases living vanquished men, made handless by this kind of trophy-taking, are brought back from battle. King Osymandyas reduced the revolted Bactrians; and "on the second wall" of the monument to him "the prisoners are brought forward: they are without their hands and members." But, though a conquered enemy may have one of his hands taken as a trophy without much endangering his life, loss of a hand so greatly diminishes his value as a slave that some other trophy is naturally preferred.

The like cannot, however, be said of a finger. That fingers are sometimes carried home as trophies we have seen; and that conquered enemies, mutilated by loss of fingers, are sometimes allowed to live as slaves, the Bible yields proof. In Judges i. 6, 7, we read: "Adonibezek [the Canaanite] fled; and they pursued after him, and caught him, and cut off his thumbs and his great-toes. And Adoni-bezek said, Threescore and ten kings, having their thumbs and their great-toes cut off, gathered their meat under my table: as I have done, so God hath requited me." Hence, then, the fact that fingers are, in various places, cut off and offered in propitiation of living rulers, in propitiation of dead rulers, and in propitiation of dead relatives. The sanguinary Feejeeans, extreme in their loyalty to cannibal despots, yield sundry illustrations. Describing the sequence of an alleged insult, Williams says: "A messenger was . . . . sent to the chief of the offender to demand an explanation, which was forthwith given, together with the fingers of four persons, to appease the angry chieftain." Again, on the occasion of a chief's death, "orders were issued that one hundred fingers should be cut off; but only sixty were amputated, one woman losing her life in consequence." And once more: a child's hand "was covered with blood, which flowed from the stump where, shortly before, his little-finger had been cut off, as a token of affection for his deceased father." This propitiation of the dead by offering amputated fingers occurs elsewhere. When, among

the Charruas, the head of the family died, "the daughters, widow, and married sisters, were obliged to have each one joint from the finger cut off; and this was repeated for every relation of the like character who died: the primary amputation being from the little-finger." By the Mandans, the usual mode of expressing grief on the death of a relation "was to lose two joints of the little-fingers, or sometimes the other fingers." A like custom was found among the Dakotas, and various other American tribes. Sacrificed in this way to the ghost of the dead relative or the dead chief, to express that subjection which would have pacified him while alive, the amputated finger becomes, in other cases, a sacrifice to the expanded ghost or god. During his initiation, the young Mandan warrior, "holding up the little-finger of his left hand to the Great Spirit, he expresses to him, in a speech of a few words, his willingness to give it as a sacrifice; when he lays it on the dried buffalo-skull, where the other chops it off near the hand with a blow of the hatchet." According to Mariner, the natives of Tonga cut off a portion of the little-finger as a sacrifice to the gods for the recovery of a superior sick relative.

Expressing originally submission to powerful beings alive and dead, this mutilation in some cases becomes, apparently, a mark of domestic subordination. The Australians have a custom of cutting off the last joint of the little-finger of females; and a Hottentot "widow, who marries a second time, must have the top joint of a finger cut off, and loses another joint for the third, and so on for each time that she enters into wedlock."

As showing the way in which these propitiatory mutilations of the hands are made so as to interfere least with usefulness, it may be noted that habitually they begin with the last joint of the little-finger, and affect the more important parts of the hand only if they recur. And we may join with this the fact that where, by amputating the hand, there is repeated in full the original mutilation of slain enemies, it is where the usefulness of the subject person is not a consideration, but where the treatment of the external enemy is extended to the internal enemy—the criminal. The Hebrews made the loss of a hand a punishment for one kind of offense, as shown in Deuteronomy xxv. 11, 12. Of a Japanese political transgressor it is said, "His hands were ordered to be struck off, which in Japan is the very extremity of dishonor." In mediæval Europe hands were cut off for various offenses; and, among sundry penal mutilations enacted by William the Conqueror, loss of a hand is one.

Recent accounts from the East prove that some vanquished men deprived of their noses by their conquerors, either while obviously alive or when supposed to be dead, survive; and those who do so remain identifiable thereafter as conquered men. Consequently, the loss of a nose may become the mark of a slave; and, in some cases, it does

this. Concerning certain ancient Central Americans, Herrera tells us that they challenged neighboring peoples when "they wanted slaves; if the other party did not accept of the challenge, they ravaged their country and cut off the noses of the slaves." And, describing a war that went on during his captivity in Ashantee, Ramseyer says the Ashantees spared one prisoner, "whose head was shaved, nose and ears cut off, and himself made to carry the king's drum."

Along with loss of nose occurs, in the last case, loss of ears, which naturally comes next to be dealt with. This is similarly interpretable as having originated from trophy-taking, and having in some cases survived; if not as a mark of ordinary slavery, still, as a mark of that other slavery which is often a punishment for crime. In ancient Mexico "he who told a lie to the particular prejudice of another had a part of his lip cut off, and sometimes his ears." Among the Honduras people a thief had his goods confiscated, "and, if the theft was very great, they cut off his ears and hands." One of the laws of an adjacent ancient people, the Miztecs, directed the "cutting off of an adulterer's ears, nose, or lips;" and by some of the Zapotecas, "women convicted of adultery had their ears and noses cut off."

But though absence of ears seems more generally to have marked a criminal than to have marked a vanquished enemy who, surviving the taking of his ears as trophies, had become a slave, we may suspect that it once did, among some peoples, mark an enslaved captive; and that, by mitigation, it gave rise to the method of marking a slave prescribed of old among the Hebrews, and which still continues in the East with a modified meaning. In Exodus xxi. 5, 6, we read that if, after his six years' service, a purchased slave does not wish to be free, his master shall "bring him to the door, or unto the door-post, and his master shall bore his ear through with an awl, and he shall serve him forever." Commenting on this ceremony, Knobel says: "In the modern East, the symbol of piercing the ears is mentioned as the mark of those who are dedicated. . . . It expresses the belonging to somebody." And since, where there grows up unqualified despotism, private slavery is joined with public slavery, and the accepted theory is that all subjects are the property of the ruler, we may suspect that there hence results in some cases the universality of this mutilation. "All the Burmese," says Sangermano, "without exception have the custom of boring their ears. The day when the operation is performed is kept as a festival; for this custom holds, in their estimation, something of the rank that baptism has in ours."

As bearing indirectly upon mutilations of this class, I may add the curious fact named by Forsyth, that the Gond holds "his ears in his hands in token of submission."

Jaws can be taken as trophies only from those whose lives are taken. There are the teeth, however; some of these may be extracted

from the jaws as trophies without seriously decreasing the usefulness of the prisoner. Hence another form of mutilation.

We have seen that teeth are worn as trophies in Ashantee and in South America. Now, if teeth are taken as trophies from captives who are preserved as slaves, loss of them must become a mark of subjection. Of facts directly showing that a propitiatory ceremony hence arises I can name but one. Among mutilations submitted to on the death of a king or chief in the Sandwich Islands, Ellis names knocking out one of the front teeth; an alternative being cutting the ears. The implication is tolerably clear; and when we further read in Cook that the Sandwich-Islanders knock out from one to four of the front teeth—when we see that the whole population becomes marked by these repeated mutilations undergone to propitiate the ghosts of dead rulers—when we infer that in propitiation of a much-dreaded ruler deified after death, not only those who knew him may submit to this loss, but also their children subsequently born—we see how the practice, becoming established, may survive as a sacred custom when its meaning is lost. For, concluding that the practice has this sacramental nature, there are the further reasons derived from the fixing of the age for the operation, and from the character of the operator. Angas tells us that in New South Wales it is the Koradger men or priests who perform the ceremony of knocking out the teeth; and of a semi-domesticated Australian Haygarth writes that he said one day, "with a look of importance, that he must go away for a few days, as he had grown up to man's estate, and 'it was high time that he should have his teeth knocked out.'" Various African races, as the Batoka, the Dor, etc., similarly lose two or more of their front teeth; and habitually the loss of them is an obligatory rite. But the best evidence (which I have found since setting down the above) is furnished by the ancient Peruvians. A tradition among certain of them was that the conqueror Huayna Ccapac, finding them disobedient, "made a law that they and their descendants should have three of their front teeth pulled out in each jaw." Another tradition, given by Cieza, naturally derivable from the last, was that this pulling out of teeth by fathers from their young children was "a service very acceptable to their gods." And then, as happens with other mutilations of which the meaning has dropped out of memory, the improvement of the appearance was in some parts the assigned motive.

It should be added that, in this case as in most cases, the mutilation assumes modified forms. "The Damaras knock out a wedge-shaped gap between their two front teeth;" "the natives in the neighborhood of Sierra Leone file or chip the teeth;" and various other tribes have allied usages.

As the transition from eating conquered enemies to making slaves of them mitigates trophy-taking so as to avoid causing death; and,

as the tendency is to modify the injury inflicted, so that it shall in the least degree diminish the slave's usefulness; and as, with the rise of a class born in slavery, the mark which the slave bears no longer showing that he was taken in war, does not imply a victory achieved by his owner—there eventually remains no need for the mark to be one involving a serious mutilation. Hence it is inferable that mutilations of the least injurious and least painful kinds will become the commonest. Such, at any rate, seems a reasonable explanation of the fact that cutting off of hair for propitiatory purposes is the most prevalent of all mutilations.

Already we have seen the probable origin of the custom among the Feejeeans that tributaries had to make a propitiatory sacrifice of their locks on approaching their great chiefs; and there is evidence that a kindred sacrifice made in homage was demanded of old in Britain. In the Arthurian legends, which, unhistoric as they may be, yield good evidence respecting the manners of the times from which they descend, we read (in Mr. Cox's abridgment): "Then went Arthur to Caerleon; and thither came messengers from King Ryons, who said: 'Eleven kings have done me homage, and with their beards I have trimmed a mantle. Send me now thy beard, for there lacks yet one to the finishing of my mantle.'"

Some reasons exist for the belief that taking an enslaved captive's hair began with the smallest practicable divergence from taking the dead enemy's scalp; for the part of the hair in some cases given in propitiation, and in other cases worn subject to a master's ownership, answers in position to the scalp-lock. The hair yielded up by the tributary Feejeeans was the *tobe*, a kind of pigtail—the implication being that this could be demanded by, and therefore belonged to, the superior. Moreover, among the Calmucks, when one pulls another by the pigtail, or actually tears it out, this is regarded as a punishable offense, because the pigtail is thought to belong to the chief, or to be a sign of subjection to him. If it is the short hair on the top of the head that has been subjected to such treatment, it does not constitute a punishable offense, because this is considered the man's own hair and not that of the chief. And then I may add the statement of Williams, that the Tartar conquerors of China ordered the Chinese "to adopt the national Tartar mode of shaving the front of the head, and braiding the hair in a long cue, as a sign of submission." Another fact presently to be given joins with these in suggesting that a vanquished man, not killed, but kept as a slave, was allowed to wear his scalp-lock on sufferance, the theory being that the victor might at any time demand it.

Be this as it may, however, the widely-prevalent custom of taking the hair of the slain, either with or without a part of the skin, has nearly everywhere resulted in the association between short hair and slavery. This association existed among both Greeks and Romans:

"The slaves had their hair cut short as a mark of servitude." We find it thus throughout America. "Socially the slave is despised, his hair is cut short," says Bancroft of the Nootkas. "The privilege of wearing long hair was rigorously denied" to Carib slaves and captives, says Edwards. The slavery that punished criminality was similarly marked. In Nicaragua "a thief had his hair cut off, and became a slave to the person that had been robbed till he was satisfied." And this badge of slavery was otherwise inflicted as a punishment. By the Central Americans a suspected adulterer "was stripped and his hair was cut (a great disgrace)." One ancient Mexican penalty "was to have the hair cut at some public place." And during mediæval times in Europe cutting of hair was enacted as a punishment. Of course there follows a correlative distinction: long hair becomes honorable. If among the Chibchas "the greatest affront that could be put on a man or a woman was to have their hair cropped;" the assimilation to slaves in appearance was the obvious reason, the honorableness of long hair being an implication. "The Itzaex Indians," says Fancourt, "wore their hair as long as it would grow; indeed, it is a most difficult thing to bring the Indians to cut their hair." Long hair is a mark of distinction among the Tongans, and none are permitted to wear it but the principal people. Similarly with the New Caledonians and various others of the uncivilized, and similarly with semi-civilized Orientals, "the Ottoman princes have their beard shaved off, to show that they are dependent on the favor of the reigning emperor." By the Greeks, "in manhood, . . . the hair was worn longer," and "a certain political significancy was attached to the hair." In Northern Europe, too, "among the Franks . . . . the serfs wore the hair less long and less carefully dressed than freemen," and the freemen less long than the nobles: "The long hair of the Frank kings is sacred. . . . It is for them a mark and honorable prerogative of the royal race." Clothair and Childebert, wishing to divide their brother's kingdom, consulted respecting their nephews, "whether to cut off their hair so as to reduce them to the rank of subjects, or to kill them." I may add the extreme case of the Japanese mikado: "Neither his hair, beard, nor nails are ever [avowedly] cut, that his sacred person may not be mutilated," such cutting as occurs being done while he is supposed to sleep.

A parallel marking of divine rank may be noted in passing. Length of hair being significant of terrestrial dignity, becomes significant, too, of celestial dignity. The gods of various peoples, and especially the great gods, are distinguished by their flowing beards and long locks.

Domestic subordination, too, in many cases goes along with short hair; in low social states women commonly bear this badge of slavery. Turner tells us that in Samoa the women wore the hair short; the men wore it long. Among other Malayo-Polynesians, as

the Tahitians and New-Zealanders, the like contrast occurs. Similarly with the Negrito races. "In New Caledonia the chiefs and influential men wear their hair long, and tie it up in a semi-conical form on the top of their head. The women all crop theirs close to the very ears." And cropped heads in like manner distinguish the women of Tanna, of Lifu, of Vate, and also the Tasmanian women. A kindred mode of signifying filial subordination may be added. Yielding up of hair once formed part of the ceremony of adoption in Europe. "Charles Martel sent Pepin, his son, to Luithprand, King of the Lombards, that he might cut his first locks, and by this ceremony hold for the future the place of his father;" and Clovis, to make peace with him, became the adopted son of Alaric, by offering his beard to be cut by him.

While coming thus to imply subjection to living persons, this mutilation simultaneously came to imply subjection to dead persons. How the yielding up of hair to the dead is originally akin to the yielding up of a trophy is well shown by the Dakotas: "The men shave the hair off their heads, except a small tuft on the top [the scalp-lock], which they suffer to grow and wear in plaits over the shoulders; the loss of it is the usual sacrifice at the death of near relations:" that is, they go as near as may be to surrendering their scalps to the dead. The meaning is again seen in the account given of the Caribs: "As their hair thus constituted their chief pride, it was an unequivocal proof of the sincerity of their sorrow, when, on the death of a relation or friend, they cut it short like their slaves and captives." Everywhere among the uncivilized, kindred forms occur. Nor was it otherwise with the ancient historic races. By the Hebrews making "baldness upon their heads" was practised as a funeral rite, as was also shaving off "the corner of their beard." Similarly by Greeks and Romans, "the hair was cut close in mourning." In Greece the meaning of this mutilation was recognized. Potter remarks: "We find Electra in Euripides finding fault with Helena for sparing her locks, and thereby defrauding the dead; and he cites the statement that this sacrifice of hair (sometimes laid upon the grave) was "partly to render the ghost of the deceased person propitious." A significant addition must be made: "For a recent death, the mourner's head was shaved; for an offering to the long-dead, a single lock was cut off."

Naturally if, from propitiation of the dead, some of whom become deities, there grows up religious propitiation, the offering of hair may be expected to reappear as a religious ceremony; and we find that it does so. Already, in the just-named fact that, besides hair sacrificed at a Greek funeral, similar though smaller sacrifices were made afterward, we see the rise of that recurring propitiation characterizing worship of a deity. And when we further read that among the Greeks "on the death of any very popular personage, as a general,

it sometimes happened that all the army cut off their hair," we are shown a step toward that propitiation by unrelated members of the community at large, which, when it becomes established, is a trait of religious worship. Hence certain Greek ceremonies. "The cutting off of the hair, which was always done when a boy became an ἔφηβος, was a solemn act, attended with religious ceremonies. A libation was first offered to Hercules, . . . and the hair after being cut off was dedicated to some deity, usually a river-god." So, too, at the first time of shaving among the Romans, "the hair cut off on such occasions was consecrated to some god."

Sacrifice of hair was an act of worship with the Hebrews also. We are told of "fourscore men, having their beards shaven, and their clothes rent, and having cut themselves, with offerings and incense in their hand, to bring them to the house of the Lord;" and Krehl gives sundry kindred facts concerning the Arabians.

Curious modifications of the practice occurred in Peru. Small sacrifices of hair were continual. "Another offering," writes D'Acosta, is "pulling out the eyelashes or eyebrows and presenting them to the sun, the hills, the combles, the winds, or whatever they are in fear of. . . . On entering the temples, or when they were already within them, they put their hands to their eyebrows as if they would pull out the hairs, and then made a motion as if they were blowing them toward the idol"—a good instance of the abridgment which ceremonies habitually undergo. Lastly, when, in presence of a national calamity, extreme propitiation of a deity is to be made, we sometimes find even the ruler sacrificing his hair. During an eruption of the great volcano in Hawaii, all other offerings having failed to appease the anger of the gods, "the king Kamehameha cut off part of his own hair, which was considered sacred, and threw it into the torrent [of lava], as the most valuable offering."

One further development remains: this kind of sacrifice becomes in some cases a social propitiation. Wreaths of their own hair plaited were bestowed upon others as marks of consideration by the Tahitians. In France, in the fifth and sixth centuries, it was usual to pluck out a few hairs from the beard on approaching a superior, and present them; and this usage was occasionally adopted as a mark of condescension by a ruler, as when Clovis, gratified by the visit of the Bishop of Toulouse, gave him a hair from his beard, and was imitated in so doing by his followers. Afterward the usage had its meaning obscured by abridgment: in the times of chivalry one mode of showing respect was to tug at the mustache.

Already, when treating of trophies, and when finding that those of the phallic class, major and minor, had the same meanings as the rest, the way was opened to explain the mutilations next to be dealt with. We have seen that, when the vanquished were not killed but

preserved as slaves, it became imperative that the taking of trophies from them should neither endanger life nor be highly injurious; and that hence, instead of jaws, teeth were taken; instead of hands, fingers; instead of scalps, hair. Similarly, in this case, the fatal mutilation disappearing left only such allied mutilation as did not seriously, or at all, decrease the value of the enslaved enemy.

That castration was initiated by trophy-taking I find no direct proof; but there is direct proof that prisoners have in some cases been treated in the way that trophy-taking of the implied kind would entail. Of Theobald, Marquis of Spoleto, we read in Gibbon that "his captives .... were castrated without mercy;" and, for thinking that there was once an enforced sacrifice of the kind indicated made to a conqueror, there is the further reason that we find a parallel sacrifice made to a deity. At the annual festivals of the Phrygian goddess Amma [Agdistis], "it was the custom for the young men to make themselves eunuchs with a sharp shell, crying out at the same time, 'Take this, Agdistis!'" There was a like practice among the Phœnicians; and Brinton names a severe self-mutilation of the ancient Mexican priests which seems to have included this. Coming in the way shown to imply subordination, this usage, like many ceremonial usages, has in some cases survived where its meaning is lost. The Hottentots enforce semi-castration at about eight or nine years of age; and a kindred custom exists among the Australians.

Naturally, of this class of mutilations, the less serious is the more prevalent. Circumcision occurs among unallied races in all parts of the world—among the Malayo-Polynesians in Tahiti, in Tonga, in Madagascar; among the Negritos of New Caledonia and Feejee; among African peoples, both of the coast and the interior, from Northern Abyssinia to Southern Caffre-land; in America, among some Mexican peoples, the Yucatanese, and the people of San Salvador; and we meet with it again in Australia. Even apart from the fact that their monuments prove it to have been practised by the Egyptians from their earliest recorded times, and even apart from the reasons for believing that it prevailed among the Arabian peoples at large, these proofs that circumcision is not limited to region or race sufficiently dispose of the current theological interpretation. They sufficiently dispose, too, of another interpretation not uncommonly given; for a general survey of the facts shows us that, while the usage does not prevail among the most cleanly races in the world, it is common among the most uncleanly races. Contrariwise, the facts taken in the mass are congruous with the general theory thus far verified.

It was shown that among the Abyssinians down to recent times the trophy taken by circumcision from an enemy's dead body is presented by each warrior to his chief, and how all such trophies taken after a battle are eventually presented to the king. If the vanquished enemies, instead of being killed, are made slaves, and if the warriors

who have vanquished them continue to present the usual proofs of their prowess, there must arise the circumcision of living captives, who thereby become marked as subjugated persons. A further result is obvious. As the chief and the king are propitiated by bringing them these trophies taken from their foes, and, as the primitive belief is that a dead man's ghost is pleased by whatever pleased the man when alive, there will naturally follow a presentation of such trophies to the ghost of the departed ruler. And then where in a highly-militant society governed by an absolute despot, divine by descent and nature, who, owning the entire population, requires them all to bear this badge of servitude, and who, dying, has his dreaded ghost anxiously propitiated, we may expect that the offering of these trophies taken from enslaved enemies to the king will develop into the offering of like trophies taken from each generation of male citizens to the god in acknowledgment of their slavery to him. Hence, when Movers tells us that among the Phœnicians circumcision was "a sign of consecration to Saturn," and when proof is given that of old the people of San Salvador circumcised "in the Jewish manner, offering the blood to an idol," we are shown just the results to be anticipated as eventually arising.

That this interpretation applies to the custom as made known to us in the Bible, there is clear evidence. We have already seen that the ancient Hebrews, like the modern Abyssinians, practised the form of trophy-taking which necessitates this mutilation of the dead enemy; and, as in the one case, so in the other, it follows that the vanquished enemy, not slain, but made prisoner, will by this mutilation be marked as a subject person. That circumcision was among the Hebrews the stamp of subjection, all the evidence proves. On learning that among existing Bedouins, as Mr. Palgrave shows, the only conception of God is that of a powerful living ruler, the sealing by circumcision of the covenant between God and Abraham becomes a comprehensible ceremony. There is furnished an explanation of the fact that, in consideration of a territory to be received, this mutilation, submitted to by Abraham, implied that "the Lord" was "to be *a* god unto" him; as also the fact that the mark was to be borne not by him and his descendants exclusively, as favored individuals, but also by slaves not of his blood. And, on remembering that in primitive beliefs the returning double of the dead potentate is believed to be indistinguishable from the living potentate, we get an interpretation of the otherwise strange tradition narrated in Exodus concerning God's anger with Moses for not circumcising his son: "And it came to pass by the way in the inn that the Lord met Moses, and sought to kill him. Then Zipporah took a sharp stone, and cut off the foreskin of her son, and cast it at his feet." That circumcision among the Jews was a mark of subordination to Jahveh is further implied by the facts that under the foreign ruler Antiochus, who brought in foreign

gods, circumcision was forbidden, and those who, persevering in it, refused obedience to these foreign gods, were slain; while contrariwise Mattathias and his friends, loyal to the god of their fathers, and rebelling against foreign rule and worship, are said to have gone "round about, and pulled down the altars: and what children soever they found within the coast of Israel uncircumcised those they circumcised valiantly." Moreover Hyrcanus, having subdued the Idumeans, made them submit to circumcision as a condition of remaining in their country; and Aristobulus similarly imposed the mark on the conquered people of Iturea.

Quite congruous are certain converse facts. Mariner states that Tooitonga (the great divine chief of Tonga) is not circumcised, as all other men are: being unsubordinated, he does not bear the badge of subordination. And with this I may join a case in which whole tribes belonging to a race ordinarily practising circumcision are uncircumcised where they are unsubordinated. Naming certain Berbers in Morocco as thus distinguished, Rohlfs says: "These uncircumcised tribes inhabit the Rif Mountains. . . . All the Rif mountaineers eat wild-boar, in spite of the Koran law."

Besides mutilations entailing some loss of flesh, bone, skin, or hair, there are mutilations which do not imply a deduction—at least not a permanent one. Of these we may take, first, one which sacrifices a liquid part of the body, though not a solid part.

Bleeding as a mutilation has an origin akin to the origins of other mutilations. Did we not find that some uncivilized tribes, as the Samoyeds, drink the warm blood of animals—did we not find among existing cannibals, such as the Feejeeans, proofs that savages drink the blood of still-living human victims—it would seem incredible that from taking the blood of a vanquished enemy was derived the ceremony of offering blood to a ghost, and to a god. But when to accounts of horrors like these we join accounts of kindred ones which savages commit, such as that among the Amaponda Caffres "it is usual for the ruling chief, on his accession to the government, to be washed in the blood of a near relative, generally a brother, who is put to death on the occasion;" and when we infer that, before the rise of civilization, the sanguinary tastes and usages now exceptional were probably general, we may suspect that from the drinking of blood by conquering cannibals there arose some kinds of blood-offerings—at any rate, those of blood taken from immolated victims. Possibly some offerings of blood from the bodies of living persons are to be thus accounted for; but those which are not are explicable as sequences of the widely-prevalent practice of establishing a sacred bond of mutual obligation between living persons by partaking of each other's blood—the derived conception being that those who give some of their blood to the ghost of the man just dead and lingering near

effect with it a union which on the one side implies submission, and on the other side friendliness.

On this hypothesis we have a reason for the great prevalence of self-bleeding as a funeral-rite, not among existing savages only, but among ancient and partially-civilized peoples—the Jews, the Greeks, the Huns, the Turks. We are shown how there arise kindred rites as permanent propitiations of those more dreaded ghosts which become gods—such offerings of blood (now taken from slain victims, now from their own bodies, and now from their newly-born infants) as those which the Mexicans gave the idols of their cannibal deities; such offerings as were implied by the self-gashings of the priests of Baal; and such as were sometimes made even in propitiating Jahveh—as by the fourscore men who came from Shechem, Shiloh, and Samaria. Moreover, the instances of bloodletting as a complimentary act in social intercourse cease to be inexplicable. During a Samoan marriage-ceremony the friends of the bride, to testify their respect, "took up stones and beat themselves until their heads were bruised and bleeding." In his account of the Central Americans, Martyr says, "When the Indians of Potonchan receive new friends, . . . as a proof of friendship, they, in the sight of the friend, draw some blood . . . . from the tongue, hand, or arm, or from some other part."

Here, however, my purpose in naming these offerings of blood under the head of mutilations is not so much to show their kinship of origin as to prepare the way for explaining the mutilations which result from them.

Gashings and tearings of the flesh make wounds which leave scars. If the blood-offerings which entail them are made by relatives to the departed spirit of an ordinary person, these scars are not likely to have any permanent significance; but, if they are made in propitiation of some deceased chief, not by his relatives alone, but by unrelated members of the tribe who stood in awe of him and fear his ghost, then like other mutilations they become signs of subjection. The Huns who "at the burial of Attila cut their faces with hollow wounds," in common with the Turks who did the like at royal funerals, thus inflicted on themselves marks which thereafter distinguished them as servants of their respective rulers. So, too, did the Lacedæmonians, who, "when their king died, had a barbarous custom of meeting in vast numbers, where men, women, and slaves, all mixed together, tore the flesh from their foreheads with pins and needles . . . . to gratify the ghosts of the dead." Customs of this kind would sometimes have further results. With the apotheosis of some notable king whose conquests gave him the character of founder of the nation, such marks, borne not by his contemporary followers only, but imposed by them on their children, might become national marks.

That the scars caused by propitiatory bloodletting at funerals do

become recognized as binding to the dead those who bear them, and do develop in the way alleged, we have tolerably good evidence. The command in Leviticus, "Ye shall not make any cuttings in your flesh for the dead, nor print any marks upon you," shows us the usage in that stage at which the scar left by sacrifice of blood is still a sign partly of family subordination and partly of other subordination. And the traditions of the Scandinavians show us a stage at which it betokens allegiance either to an unspecified supernatural being, or to a deceased ruler who has become a god. Odin, "when he was near his death, made himself be marked with the point of a spear;" and Niort "before he died made himself be marked for Odin with the spear-point."

That scars on the surface of the body, thus coming to express loyalty to a deceased father or a deceased ruler, or a god derived from him, initiate, among other disfigurements, those we class as tattooing, is a probable inference. Lacerations, and the traces they leave, are certain to take different forms in different places. The Andaman-Islanders "tattoo by incising the skin with small pieces of glass, without inserting coloring-matter, the cicatrix being whiter than the sound skin." Some natives of Australia have ridges raised on this or that part of the body, while others brand themselves. In Tanna the people make elevated scars on their arms and chests. And Burton, in his "Abeokuta," says: "The skin-patterns were of every variety, from the diminutive prick to the great gash and the large, boil-like lumps. . . . In this country every tribe, sub-tribe, and even family, has its blazon, whose infinite diversifications may be compared with the lines and ordinaries of European heraldry—a volume would not suffice to explain all the marks in detail." Naturally, among the various skin-mutilations originating in the way alleged, many will, under the promptings of vanity, take on a character more or less ornamental; and the use of them for decoration will often survive when their meaning has been lost.

Hypothesis apart, we have proof that these marks made by cutting gashes, or puncturing lines, or raising welts, or otherwise, are in many cases tribal marks—as they would, of course become if they were originally made when binding themselves by blood to the dead founder of the tribe. A clear exhibition of the feeling implied by the bearing of marks is contained in a statement Bancroft makes respecting the Cuebas of Central America: "If the son of a chief declined to use the distinctive badge of his house, he could, when he became chief, choose any new device he might fancy. A son who did not adopt his father's totem was always hateful to him during his lifetime." And if the refusal to adopt the family-mark where it is painted on the body is thus regarded as a kind of disloyalty, equally will it be so when the mark is one that has arisen from modified lacerations; and such refusal will be tantamount to rebellion where the mark sig-

nifies descent from, and submission to, some great father of the race. Hence, then, the meaning of such facts as the following: "All these Indians," says Cieza of the ancient Peruvians, "wear certain marks by which they are known, and which were used by their ancestors. . . . Both sexes of the Sandwich-Islanders have a particular mark (tattooed) which seems to indicate the district in which, or the chief under whom, they lived." Of the Uaupes, "one tribe, the Tucános, are distinguished from the rest by three vertical blue lines on the chin."

That a special form of tattooing becomes a tribal mark in the way suggested, we have, indeed, some direct evidence. Among sundry mutilations undergone as funeral-rites, at the death of a chief among the Sandwich-Islanders, such as knocking out teeth, cutting the ears, cutting hair, etc., one is tattooing a spot on the tongue. Here we see this mutilation acquiring the signification of allegiance to a ruler who has died; and then when the deceased ruler, unusually distinguished, is apotheosized, the tattoo-mark becomes the sign of obedience to him as a deity. "With several Eastern nations," says Grimm, "it was a custom to mark one's self by a burned or incised sign as adherent to a certain worship. . . . Philo complains of his country-people in this respect." It was thus with the Hebrews. Bearing in mind the above-quoted interdict against marking themselves for the dead, we shall see the meaning of the words in Deuteronomy—"They have corrupted themselves, the spot is not the spot of his children: they are a perverse and crooked generation." And that such contrasted spots as are here referred to were understood in later times to imply the service of different deities is suggested by passages in Revelation, where an angel is described as ordering delay "till we have sealed the servants of our God in their foreheads," and where "an hundred and forty and four thousand, having his Father's name written in their foreheads," are described as standing on Mount Sion, while an angel proclaims that, "if any man worship the beast and his image, and receive his mark in his forehead, or in his hand, the same shall drink of the wine of the wrath of God." Down to the present day in the East like marks have like meanings. Thomson, after specifying the method of tattooing, says: "This practice of marking religious tokens upon the hands and arms is almost universal among the Arabs of all sects and classes. Christian pilgrims to Jerusalem have the operation performed there, as the most holy place known to their religion." And still more definite is the statement of Kalisch, that "Christians in some parts of the East, and European sailors, were long in the habit of marking, by means of punctures and a black dye, their arms and other members of the body with the sign of the crucifix or the image of the Virgin; the Mohammedans mark them with the name of Allah." So that down to our own time among advanced races we trace in these skin-mutilations meanings like those avowedly

given to them in ancient Mexico, where, when a child was dedicated to Quetzalcohuatl, "the priest made a slight cut with a knife on its breast, as a sign that it belonged to the cult and service of the god," and, like those still avowedly given to them by negroes in Angola, where in many regions every child as soon as born is tattooed on the belly, in order thereby to dedicate it to a certain fetich.

A significant group of evidences must be added. We have seen that, where cropped hair implies servitude, long hair becomes an honorable distinction; that, shorn beards being marks of subordination, unshorn beards are marks of supremacy; and that, occasionally, in opposition to circumcision, as associated with subjection, there is absence of it along with the highest power. Here we have a parallel antithesis. The great divine chief of the Tongans is unlike all other men in Tonga, not only as being uncircumcised, but also as being untattooed. Elsewhere classes are sometimes thus distinguished. Burton says of the people of Banza Nokkoi, on the Congo, that those who are tattooed "are generally slaves." And in this relation there may be significance in the statement of Boyle that "the Kyans, Pakatans, and Kennowits, alone in Borneo practise tattooing, and these are the three aboriginal races least esteemed for bravery." Not, however, that distinctions implied by tattooing and its absence are at all regular: we here meet with anomalies. Though in some places showing social inferiority, tattooing in other places is a trait of the superior. While in Feejee only the women are tattooed—while in Tahiti there is tattooing of both men and women, in the Sandwich Islands the men are more tattooed than the women. Sometimes the presence of this skin-mutilation is evidence of high rank. "In the province of Panuco, the noblemen were easily to be distinguished, as they had their bodies tattooed." But the occurrence of anomalies is not surprising. During the perpetual overrunnings of race by race, it must sometimes have happened that, an untattooed race having been conquered by one which practised tattooing, the presence of these markings became associated with social supremacy. Moreover, since, along with dispersions of tribes and obscurings of their traditions, the meanings of mutilations will often die, while they themselves survive, there may not unnaturally occur developments of them for purposes of display, tending to reverse their original significance; as seems implied by the statement of Angas that "tattooing is a class distinction among the New-Zealanders; the faces of slaves have not the spiral tattooing;" or that of Dobrizhoffer, that "every Abiponian woman you see has a different pattern on her face. Those that are most painted and pricked you may know to be of high rank and noble birth."

But a further cause exists for this conflict of meanings. There remains to be named a species of skin-mutilation having another origin and different implication.

Besides scars resulting from lacerations made in propitiation of dead relatives, dead chiefs, and deities, there are scars resulting from wounds received in battle. The presence of many such implies many conflicts with enemies; and hence, all the world over, they are held in honor and displayed with pride. The sentiment associated with them among ourselves in past times is indicated in Shakespeare by sundry references to "such as boasting show their scars." Lafeu says, "A scar nobly got, or a noble scar, is a good livery of honor;" and Henry V. foretells of an old soldier that "then will he strip his sleeve and show his scars."

Animated as are savages in still higher degrees than civilized by the feelings thus indicated—having no other kind of honor than that derived from the reputation for bravery—what may be expected to result? Will not the anxiety to bear honorable scars sometimes lead to the artificial making of scars? We have evidence that it does. Lichtenstein tells us that the priest among the Bechuanas makes a long cut in the skin from the thigh to the knee of each warrior who has slain some of the enemy in battle. There is a kindred usage among the Bachapin Caffres. Among the Damaras, "for every wild animal that a young man destroys, his father makes four small incisions on the front of the son's body as marks of honor and distinction." And then Tuckey, speaking of certain Congo people who make scars, says that this is "principally done with the idea of rendering themselves agreeable to the women:" a motive which is intelligible if such scars originally passed for scars got in war, and implying bravery. American races yield some evidence of like meaning. We read that "the Itzaex Indians [in Yucatan] have handsome faces, though some of them were marked with lines as a sign of courage." Facts furnished by other American tribes suggest that the infliction of torture on entering maturity originated from the habit of making scars artificially in imitation of scars bequeathed by battle. If self-injury to avoid service in war has in all times been frequent among those lacking courage, we may reasonably infer that among the more courageous, who have received no wounds, self-injury might be not unfrequent, where there was gained by it that character for bravery desired above everything. Though at first secret and exceptional, the reputation achieved might make it gradually more common and at length general; until, finally, public opinion, vented against those who did not follow it, made the usage peremptory. When we read in Dobrizhoffer that, among the Abipones, "boys of seven years old pierce their little arms in imitation of their parents, and display plenty of wounds," we are shown the rise of a feeling, and a consequent practice, which, growing, may end in a system of initiatory tortures at manhood. Hence, when of the Arawaks Schomburgk tells us that after a Mariquarri dance the blood will be running down their swollen calves, and strips of skin and muscle hang down the

mangled limbs, we may suspect that in this and kindred self-mutilations we see an outcome of the ambition to bear honorable scars. Though, when the scars, being borne by all, are no longer distinctive, discipline in endurance comes to be the reason given for inflicting them, this cannot well have been the original reason; since primitive men, improvident in all ways, are very unlikely to have deliberately devised and instituted a usage with a view to a foreseen distant benefit: the assumption of anything like a legislative act is inadmissible.

However this may be, we have here a second origin for certain kinds of mutilations. And hence a probable reason why markings on the skin, though generally badges of subordination, become in some cases honorable distinctions and occasionally signs of rank.

Something must be added concerning a secondary motive for mutilation; parallel to, or sequent upon, a secondary motive for taking trophies.

In the last chapter we inferred that, prompted by his belief that the spirit pervades all parts of the corpse, the savage preserves relics of dead enemies partly in the expectation that he will be enabled thereby to coerce their spirits—if not himself, still by the help of the medicine-man. He has a parallel reason for preserving a part cut from one whom he has enslaved: both he and the slave think that he so obtains a power to inflict injury. When we find that the sorcerer's first step is to procure some hair or nail-parings of his victim, or else some piece of his dress pervaded by that odor which is identified with his spirit, it appears to be a necessary corollary that the master who keeps by him the tooth of a slave, a joint of his finger, or even a lock of his hair, thereby retains a power of delivering him over to the necromancer, who may bring on him one or other fearful evil—torture by demons, disease, death.

Thus it seems possible that, where the part cut off is preserved, mutilation has a secondary governmental effect. The subjugated man is made obedient by a dread akin to that which Caliban expresses of Prospero's magically-inflicted torments.

The evidence that bodily mutilation of the living has been a sequence of trophy-taking from the dead, is thus at once abundant and varied. As the taking of the trophy implies victory carried even to the death, the derived practice of cutting off a part from the living prisoner comes to imply subjugation; and eventually the voluntary surrender of such a part expresses submission, and becomes a propitiatory ceremony because it does this.

Hands are cut off from dead enemies; and, answering to this, besides some identical mutilations of criminals, we have the cutting-off of fingers or portions of fingers, to pacify living chiefs, deceased per-

sons, and gods. Noses are among the trophies taken from slain foes; and we have loss of noses inflicted on prisoners, on slaves, on transgressors of certain kinds. Ears are brought back from the battle-field; and occasionally they are cut off from prisoners, criminals, or slaves; while there are people among whom pierced ears mark the servant or the subject. Jaws and teeth, too, are trophies; and teeth, in some cases knocked out in propitiation of a dead chief, are, in various other cases, knocked out by a priest as a quasi-religious ceremony. Most prevalent and complete is the evidence furnished by mutilation of the hair. Scalps are taken from killed enemies, and sometimes their hair is used to decorate a victor's dress; and then come various sequences. Here the enslaved have their heads cropped; here scalp-locks are worn subject to a chief's ownership, and these are demanded in sign of submission; while, elsewhere, men are shorn of their beards to ornament the robe of a superior: unshorn hair being thus rendered a mark of rank. Among numerous peoples, hair is sacrificed to propitiate the ghosts of relatives; whole tribes cut it on the deaths of their chiefs or kings; it is yielded up to express subjection to deities; occasionally it is offered to a living superior in token of respect; and this complimentary offering is extended to others. Similarly with genital mutilations, there is a like taking of parts from slain enemies and from living prisoners; and there is a presentation of them to kings and to gods. Nor is it otherwise with mutilations of another class. Self-bleeding, initiated partly, perhaps, by cannibalism, but more extensively by the mutual giving of blood in pledge of loyalty, enters into several ceremonies expressing subordination: we find it occurring in propitiation of ghosts and of gods, and occasionally as a compliment to living persons. Naturally it is the same with the resulting marks. Originally indefinite in form and place, but rendered definite by custom, and at length often decorative, these healed wounds, at first entailed only on relatives of deceased persons, then on all the followers of a man who was much feared while alive, so became marks expressive of subjection to a dead ruler, and eventually to a god: thus growing into tribal and national marks.

If, as we have seen, trophy-taking as a sequence of conquest enters as a factor into those governmental restraints which conquest initiates, it is to be inferred that the mutilations originated by trophy-taking will do the like. The evidence justifies this inference. Beginning as marks of personal slavery, and becoming marks of political and religious subordination, they play a part like that of oaths of fealty and pious self-dedications. Moreover, being public acknowledgments of submission to a ruler, visible or invisible, they enforce authority by making conspicuous to all eyes the extent of his sway. And where they signify class-subordination, as well as where they show the subjugation of criminals, they further strengthen the hands of the regulative agency.

If mutilations originate as alleged, we may expect to find some connection between the extent to which they are carried and the social type as simple or compound, militant or industrial. On grouping the facts as presented by fifty-two peoples, the connection emerges with as much clearness as can be expected. In the first place, since the development of mutilation as a custom goes with conquest, and resulting aggregation, it is inferable that simple societies, however savage, will be less characterized by it than the larger savage societies compounded out of them, and less than even the semi-civilized societies. This proves to be true. Of peoples who form simple societies that practise mutilation either not at all or in slight forms, I find, among races wholly unallied, eleven—Fuegians, Veddahs, Andamanese, Dyaks, Todas, Gonds, Santals, Bodo and Dhimals, Mishmis, Kamtchadales, Snake Indians; and these are characterized throughout either by absence of chieftainship, or by chieftainship of an unsettled kind. Meanwhile, of peoples who mutilate little or not at all, I find but two in the class of compound societies; of which one, the Kirghiz, is characterized by a wandering life that makes subordination difficult, and the other, the Iroquois, had a republican form of government. Of societies practising mutilations that are moderate, the simple are relatively fewer, and the compound relatively more numerous: of the one class there are ten—Tasmanians, Tannese, New Guinea people, Karens, Nagas, Ostiaks, Esquimaux, Chinooks, Comanches, Chippewyans; while of the other class there are five—New-Zealanders, East Africans, Khonds, Kukis, Calmucks. And of those it is to be remarked that in the one class the simple headship, and in the other class the compound headship, is unstable. On coming to the societies distinguished by severer mutilations, we find these relations reversed. Among the simple I can name but three—the New Caledonians (among whom, however, the severer mutilation is not general), the Bushmen (who are believed to have lapsed from a higher social state), and the Australians (who have, I believe, similarly lapsed); while, among the compound, twenty-one may be named—Feejeeans, Sandwich-Islanders, Tahitians, Tongans, Samoans, Javans, Sumatrans, Malagasy, Hottentots, Damaras, Bechuanas, Caffres, Congo people, coast negroes, inland negroes, Dahomans, Ashantees, Fulahs, Abyssinians, Arabs, Dakotas. Social consolidation being habitually effected by conquest, and compound and doubly-compound societies being, therefore, during early states, militant in their activities and types of structure, it follows that the connection of the custom of mutilation with the size of the society is indirect, while that with its type is direct. And this the facts show us. If we put side by side those societies which are most unlike in respect of the practice of mutilation, we find them to be those which are most unlike as being wholly unmilitant in organization, and wholly militant in organization. At the one extreme we have the Veddas, Todas, Bodo and Dhimals; while, at

the other extreme, we have the Feejeeans, Abyssinians, ancient Mexicans.

Derived from trophy-taking, and developing with the development of the militant type, it is to be anticipated that mutilations decrease as fast as the societies consolidated by militancy become less militant, and disappear as the industrial type of structure evolves. That they do so European history at large may be assigned in proof. And it is significant that in our own society, now predominantly industrial, such slight mutilations as continue are connected with that regulative part of the organization which militancy has bequeathed: there survive only the now-meaningless tattooings of sailors, the branding of deserters, and the cropping of the heads of felons.

THE EUCALYPTUS IN THE FUTURE.

By Professor SAMUEL LOCKWOOD.

A LITERARY venture of our boyhood comes upon us like the aroma of tropical fruit eaten for the first time. An uncle had given his eight-year-old favorite a silver sixpence. Never before had the youngling possessed so much money in his own right. Soon the young capitalist found himself confronting the shop-window of the nearest stationer, where his eyes became riveted to a little book—"Life and Voyages of La Pérouse," price sixpence. The book was eagerly bought, and it proved an exciting *morceau*. This same Jean François de Galaup, Count de la Pérouse, when about thirty-seven years old, served in the American Revolution. In 1782 he led a small fleet into Hudson Bay, and destroyed the English trading-post. But Louis XVI. found that, while he had been helping to wrest the colonies from Great Britain, she was adding to herself new glory, and vast territories, by the discoveries of her great navigator, Captain Cook. So the French monarch dispatched La Pérouse, with two ships, on a mission of exploration in the Pacific. Neither the bold navigator nor any of his men saw home again. The last known of the expedition was from a letter written by La Pérouse at Botany Bay, February 7, 1788. Three years after, a French squadron was sent to search for the great *voyageur*, but in vain. With this expedition went as naturalist the famous botanist La Billardière. In Tasmania he found the most extraordinary arboreal flora he had ever seen. Especially wonderful for number and size was one tree, to which he gave the generic name *Eucalyptus*, meaning "well-covered," alluding to the singular form of the flower-bud, which has on it an operculum or cover not unlike the lid of a tiny sugar-bowl (see the object between the flower and the fruit at foot of Fig. 3). Thus the

unexpanded flower-bud, being cup-like below and cone-like at top, was not dissimilar in form to the globular brass button formerly in vogue, and so the blue-gum received from this botanist the specific name *globulus*.

FIG. 1.—EUCALYPTUS PREISSIANA.

"One tree of the future—one of hope," says Prof. Flückiger, "may be recognized in *Eucalyptus globulus*." And the prophecy is advancing to fulfillment, for already the eucalypt is becoming a cosmopolitan tree. It was discovered by La Billardière on the south of the island of Tasmania, near Entrecastenaux Channel, May 6, 1792. But, though soon after known to science, not until 1856 was it known to the arboriculturists of the Old World. In that year M. Ramel sent seeds from Melbourne to Paris. In 1857, and again in 1860, larger supplies arrived, which, being distributed, found their way over a great part of the civilized world. Of the many varieties of eucalypts, the blue-gum, or *Eucalyptus globulus*, was the first to be introduced into Europe; hence, perhaps, it may yet appear that the best variety for acclimatization has not received proper attention. The *Eucalyptus globulus* is only found in Tasmania and Victoria, but where found it is really the monopolist of the woods. The forest area of Victoria, the most southern colony of Australia, contains 73,000 square miles of forest, of which 71,500 is almost wholly of eucalypts. And so great is the diversity of these trees among themselves, that some one hundred and fifty varieties are recognized. This gave marked interest to the exhibits of the Australian colonies and Tasmania in the Philadelphia Exposition. But to the student of human progress a noteworthy fact was, that this *Eucalyptus* figured in the contributions of nations to whom the seed even was unknown twenty years ago. Eucalyptus woods, leaves, oils, essences, gums, etc., formed items in the exhibits from the south and the north of Africa,

the Cape Colony and Algeria; the Orange Free State, Southern Europe, notably France and Italy, Brazil, the pampas of South America, Mexico, California, Jamaica, and even India, could have competed. Hence it would be no fiction to pronounce to-day that the *Eucalyptus* is the cosmopolitan tree.

But our subject is interesting to three kinds of observers—the economist, or utilitarian, the botanist, and the geologist. Let us ask of each one a free-hand sketch.

The first, who is a matter-of-fact personage, adduces the *economic* uses of these gum-trees, as the Eucalypts are frequently called. When freshly cut the wood of these trees is soft, but so full is it of a resinous gum that it soon hardens, and becomes wellnigh imperishable. For ships, and docks, and jetties, it is invaluable. The terrible *Teredo navalis*, or ship-worm, lets it alone. It is proof also against that fearful scourge the termites, or white ant. Hence, in India, eucalyptus-wood is used for the sleepers of the railroads, where it defies the insects and the climate. So great is the variety of the eucalypts, that they are provident for nearly every purpose which wood can subserve. The ship-builder, wheelwright, carpenter, coach-maker, and cabinet-makers, are all supplied. Usually the eucalypts are evergreens, and hold tenaciously to their leaves. But they readily shed their bark, as a rule, and in such immense pieces can this be detached that the natives make a rude tent of a single piece. Of many species the bark is serviceable for paper-making. For size no trees can equal these Australian gums in the magnitude of the timber afforded. A plank sent from Victoria, and intended for the London Exhibition, but which arrived too late, sold for £100. It was a clear plank, over 223 feet long, two feet six inches wide, and three inches thick. But, though excellent timber, some of the species are of little worth for fuel. In these the wood burns with such difficulty that it is regarded as specially suited for shingles.

These gum-trees are the Titans of the race. In the deep ravines of Dandenong, in Victoria, a *Eucalyptus amygdalina* measured 420 feet; while another, on the Black Spur, measured 480 feet, thus overtopping greatly the Pyramid of Cheops and every human achievement, and even beating by 155 feet the famous *Sequoia gigantea* (Torrey) ("Keystone State"), the biggest of the "big trees" of the Calaveras grove. Mr. G. W. Robinson found a eucalypt, which, at the height of four feet from the ground, had a girth of 81 feet, or 27 feet diameter. It is notable, too, that for amount of timber per acre these gum-trees are unmatchable. We read that, in one of the densest parts of the Mount Macedon state forest, an acre of *Eucalyptus fissilis* contained forty-two large standing trees and twelve saplings. Many of the largest of these trees were from six to seven feet in diameter four feet from the ground, and were from 200 to 220 feet high. Nor do such altitudes necessarily indicate a very high antiquity. The rapidity of

growth is wonderful. Saplings fifty feet high, and but ten years old, are not remarkable. It is declared that seed sown in Jamaica at an elevation of 5,000 feet, in 1870, had in 1876 attained a growth of fifty feet. We have with our own eyes witnessed throughout an entire summer a growth of an inch a day. No one understood so well as Baron von Müller the nature and capacities of the *Eucalyptus*. He more than all others has made the world acquainted with it. With him was a scientific faith that this was the world's tree of promise. In this tree of Australia he saw the means with which to obliterate from the hydrographic map the rainless zones, to clothe with wood the desolate ranges of Tunis, Algeria, and Morocco, and render habitable parts of the Great Sahara, by indefinitely expanding the oases, to restore fertility to the Holy Land, to give rain to the Asiatic plateau, or the desert of Atacama, and furnish timber and fuel to Natal and La Plata.

None better than the baron, however, knew that, while able to stand great heat, these rapidly-growing eucalypti cannot resist great cold, and without these home conditions we must not expect of them their home achievements. Even at home the tribe does its best with its semi-tropical members. And there is a great range of variety until we meet even the Alpine species, of slow growth and very modest altitude. Skill and patience may do much; but in our country, except in a few favored spots, little can be hoped of the semi-tropical varieties north of latitude 30°, until acclimatization shall have been effected.

But it is claimed for the eucalypts that their presence is hygienic, or sanatory, especially in malarial regions. That the *E. globulus* has earned by fair experiment its name of fever-tree, as a preventive, seems now to be settled. Its rapid growth must make it a great drainer of wet soils, while its marked terebinthine odor may have its influence, and it is highly probable that the liberation of this essence into the air stands connected with its generation of ozone. But, whatever the sanatory activities of the eucalypt may be, the fact is squarely settled that spots in Italy, uninhabitable because of malarial fever, have been rendered tolerable by the planting of *E. globulus*, and it is believed that a more plentiful planting would nearly if not quite remove the difficulty. A military post is mentioned in Algeria, in which the garrison had to be changed every five days, such was the virulence of the malaria. A plantation of eucalypts cleared the miasma nearly away, and rendered unnecessary the frequent changes of the garrison. In this case 60,000 trees were planted.

But the eucalyptus has not a few medicinal virtues. Its oils and essences are antiseptic. Diffused in the sick-room, they purify the air and generate ozone. Already they have taken their places in the materia medica as very important internal medicines. The leaves contain the essence *eucalyptol*, and a resinous solid containing a bitter principle not yet understood, and which seems to afford the antifebrile

virtue; hence an extract from the leaves, either aqueous or alcoholic, is used as a febrifuge. As a tonic, water may be aromatized by a slight infusion of the leaves. A liquor similar to that of mastic can be produced, and the pharmacy gives instructions for making a tonic eucalyptal wine. Some of the species are tapped for the sap, and gum-tree cider is obtained; the leaves of others yield manna. The famous East India kino of commerce, obtained from the *Pterocarpus marsupium*, a lofty legume growing on the mountains of India, now finds a rival in the Botany Bay kino, the concrete juice of the brown gum-tree (*Eucalyptus resinifera*), of which it is said that a single tree is capable of furnishing 500 pounds of kino in a year. In a word, in the modern pharmacopœia, eucalyptus, with its many preparations, occupies considerable space. A very interesting instance of what the therapeutist calls "masking" is an application of the oil of eucalypt for the deodorizing and aromatizing of cod-liver oil, thus rendering palatable and even additionally tonic this repulsive medicine.

At the Intercolonial Exhibition of 1866, in Australia, Baron von Müller caused to be exhibited, as from the Phyto-Chemical Laboratory of Victoria, tannic acid, gallic acid, pure wood-spirits, pure acetic acid, distilled wood-vinegar, and other products, obtained from several species of eucalyptus. Mr. Bosisto, a chemist of Victoria, sent to the Philadelphia Exhibition the following products of the one species (*E. globulus*): Essential oil—a tonic, stimulant, antiseptic, anthelmintic; eucalyptol, for inhalation in bronchial or throat affections; eucalyptic acid; liquor of eucalyptus globulus—stimulant in ague or low fever; tincture of eucalyptus globulus—stimulant, tonic, antiperiodic; powder of eucalyptus globulus—antiseptic, cataplasma; cigarettes of eucalyptus globulus—disinfectant, employed in bronchial or asthmatic affections. But many mysteries are waiting solution in the laboratory of the pharmacist. New substances are to be discovered, and those already known will be better understood; all which revealings will be as new fruits on this tree of the future.

But let us hear the botanist's story. He says the thing has been a good deal of a bother to him; that he thought these gum-trees of Australia were pretty much like the animals there, specimens of Nature's jokes. Indeed, we find a recent authority saying, "Nine-tenths of the 8,000 species of plants in Australia are unknown elsewhere, and entirely unconnected with the forms of vegetation of any other division of the world." And then to think of the great variety of forms in this one genus, *Eucalyptus*. In one the leaves, six or seven inches long, are but a quarter of an inch wide, almost grass-like; while the leaves of the messmate, or *E. amygdalina*, are almond-shape, and nearly as wide as they are long. Those of *E. Preissiana* are bluntly rounded at the ends (Fig. 1), while the big-berry-gum-tree, *E. macrocarpa* (Fig. 2), has wide leaves with mucronate points. Compare these with the outline Fig. 3 of *E. globulus*, with its sickle-shaped leaves, ten

inches long, in the specimen from which this was sketched. Alluding to the difficulty in defining the species, Woolls says, "Botanists, from Robert Brown to Baron Müller, have endeavored to reduce the varying forms to systematic arrangement," but without success. And a vast amount of acumen and ingenuity has been brought to the task; such as the consideration of the operculum or cap of the flower-bud, and the length of the pistil. Compare the long pistil in the seed-vessel of *E. Preissiana*, left side of Fig. 1, with the short one in the

FIG. 2.—EUCALYPTUS MACROCARPA.

flower of *E. Globulus*, in Fig. 3. The form of the anthers and the seed-vessels, and the texture of the bark, have all been taken as factors of the problem.

Owing to the bluish-green of its leaves, *E. globulus* is popularly known as the blue-gum tree. Abroad it is most known outside of its systematic name as the Tasmanian gum-tree, and Australian fever-tree. Among the settlers, gum-tree is the general name of the eucalypts. But, as might be expected of a genus so numerous in species, there are many trivial names, such as blue-gum, brown-gum, the red and the white mahogany, stringy-bark, and iron-bark, etc. The botanists reckon 150 varieties. These all belong to the great order *Myrtaceæ*, or myrtle-blooms. And a decidedly respectable relationship have these trees which shed "their medicinal gum," for they are close cousins to the well-known myrtle, the pomegranate, pimento, or allspice, cajeput, and clove. The flowers of this order are known in their structure as calycifloral. Perhaps this curious blending, or confusion, of the calyx and the corolla, is shown most interestingly in the flowers of these eucalypts. The calyx is really in two distinct parts, a woody cup below with an operculum or lid above. (*See* middle figure, bottom of cut 3.) When the flower is ready to open it pushes

up, and thrusts off the calyx-cover, which falls to the earth, carrying with it the dubious corolla, which is intimately united to it on its inside. Thus, what is left is the lower part of the calyx, which is really a woody cup, with its pistillate organs in the centre. But, though a cup-like body, it has four rib-like markings on the outer side, which

FIG. 3.—EUCALYPTUS GLOBULUS: ADULT LEAVES, FLOWER, BUD, AND FRUIT.

plainly indicate the sepaloid divisions. Look at the fruit, or seed-capsule, which is given about the natural size at the bottom and to the right of Fig. 3. Bristling from the inner rim or edge of the calyx, stand the thread-like stamens, each with its golden anthers atop, making a showy display for what would otherwise be, from its extreme simplicity, a very unhandsome flower.

The growth of the young eucalypt affords some points of strange interest. There is the rapidity of growth of the three species which have been best tried, and which certainly will figure largely as the world's future timber-trees: *E. globulus*, the blue-gum; *E. gigantea*, the stringy-bark; and *E. amygdalina*, the messmate, or peppermint-tree.

The one best known in experiments at acclimatizing is the blue-gum. We have followed its growth from seeds planted by ourselves. Last October we saw in the back-yard of Dr. R. E. Kunzè, of this city, a eucalypt scarcely a year old, and over twelve feet in height. For four or five months it averaged an inch a day. Blue-gums but seven years from the seed have been known to reach a height of sixty-five feet, with a girth of stem near the ground of forty-five inches.

But, for all this rapidity of growth, the young eucalypt seems to be doggedly resolved that for some years at least it shall resemble its parent in no particular save one, namely, the aromatic odor of its leaves.

Suppose we compare Figs. 3 and 4, the one representing a young eucalypt, and the other an adult—that is, one old enough to bear flowers and seeds. Notice the stem of the young tree, Fig. 4, that it

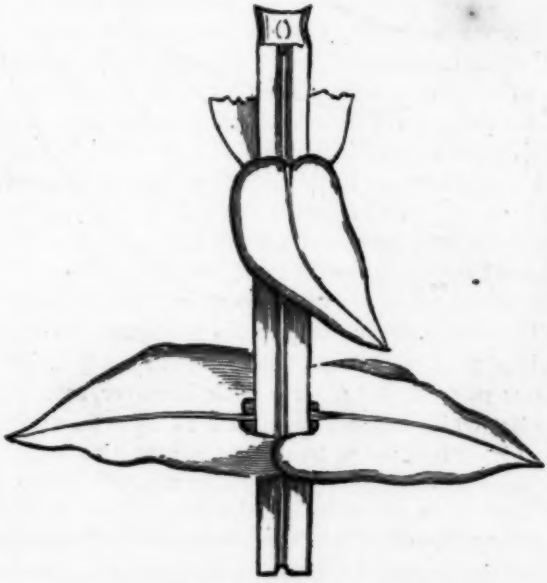

Fig. 4.—Eucalyptus Globulus: A Young Tree.

is square, or four-sided, like those of the labiates, or Mint family of plants. On each side of this square stem is a depression, within which the leaf is attached, which, technically, may be said to be amplexicaul, or embracing, as it half surrounds the stem, and this at some disadvantage, since the attachment is not at the angle, but flush upon the side of the stem. The leaf is sessile, having no appreciable petiole or foot-stalk. And the leaves are opposite, so that each pair is set at right angles, or crosswise to the pair next below it or next above it. And the leaves are cordate, or heart-shaped, being deeply

notched at the base, so that the lobes of one leaf lap over or lie upon the lobes of the other, thus appearing at first sight, by deception, like the perfoliate leaves on the upper part of a honeysuckle. Each leaf, too, has its upper and its lower plane, the upper one being exposed to the sunlight, and the under one being kept in the shade. The two sides of the leaf differ physiologically, as the stomata, or breathing-organs, are on the under side of the leaf. The leaves, too, of the young eucalypt are bright, grassy green; they are also thin, and the tissue soft and somewhat succulent.

Now, not one of these particulars is carried into the maturity of the tree. Perhaps, in its enlarged arboreal wisdom, the big gum-tree eschews them all as the indiscretions of its youth. So the labiate character, or four-sidedness, gives place to a round stem. The leaves are now not amplexicaul, but stand well out from the branch-stems, and sometimes even hang suspended. They have now long petioles, or leaf-stems. In fact, as against the former sessile character of the leaf, the difference is almost forced to the point of exaggeration, since in *E. globulus* the long-lanceolate leaf seems really an extension and expansion of the petiole, or leaf-stalk. The leaves are no longer opposite, but alternate, nor are they heart-shaped, but long-lanceolate, and often even falcate, or scythe-shaped. Their color is now not grass-green, but bluish-green, and the points are tipped with red. The tissue, too, is changed, for the leaves are thick, and leathery, and dry. Nor has the leaf now its sunny side and its shady side distinct—that is, the blade has no upper or lower plane, but an upper and a lower edge, the one edge being set toward the sky and the other toward the earth, thus exposing both planes equally to the sunlight. To accomplish this eccentric adjustment of the leaf, the petiole actually twists itself, as if it really knew what it was about—with, however, seemingly some of that discomfort which attends on strained etiquette. Often the twist or contortion is so evident as to arrest the attention at once; and the amount of torsion is wonderful when it is mentioned that the petiole seems to delight in holding the scythe-shaped leaf with its concave edge uppermost (Fig. 3). It is surely curious to find in the leaves of the adult tree the texture so different from that of the leaves of its youth. But the leaf is now the seat of a much greater physiological change. The two planes of the leaf are now virtually alike—the same in texture and in organs. The ribs and veins are the same, alike prominent on each side, much as if the roof of a house should have its beams and rafters inside and out. And two series of stomata, or breathing-organs, now appear—one series for each side of the leaf. Here, we think, lies much of the secret of the great draining capacity of the eucalypts. Both sides of the leaf work equally. It is as the double-cylinder engine against the single one. It is asserted of the gum-tree that it can eliminate from a swampy soil eight times its own weight of water in twenty-four hours.

What, then, is the logic of these facts? Let us give the geologist the last word; for it may be that, from his habit of dealing with the floras and the faunas of the long ago, his generalization may be more profound than that of the mere systematic botanist.

What about the eccentricities of the young eucalypt? Our mentor here denies the eccentricity in the sense of freakiness. He sees in it a law of the Creator. The young eucalypt, he thinks, in its marvelous vigor of growth, is tending to, or striving after, the forms and conditions of the higher and more recent groups; but that, with something of its growth-vigor abated in the adult state, it reverts back to its legitimate ancestral type. But we may not be too knowing; and surely a devout science can well afford to admit with reverence that "His ways are past finding out."

And this delver in the earth after organic relics assures us that these eucalypts are an extremely ancient race, and that they were formerly wide-spread. He even finds them in the Eocene times, composing in part the great forests of Europe. These, he tells us, were the arboreal ancestors of the gum-trees of Australia; and he bids us note that, of the existing floras of the world, that of Australia has the highest antiquity. With this instance, as almost paralleled, we may adduce the "big trees" of California. There can be no doubt that these gigantic and graceful trees once covered a large area, extending into an antiquity scarcely less ancient than that of the eucalypts. Even snow-clad Greenland in that ancient time had its flowery age, and was a home for the princely sequoias. Now, what reduced them to but two species, and what pushed them over the mountains, and bade them be content with that small domain centred by the Calaveras grove? And what a change must earth have undergone, that Australia should be isolated from its once-continental alliance, and these noble eucalypts, the tallest Titans that the world has known, should be thus put upon their limits! The sequoias promise little, and seem doomed ere long to pass away. Beyond their beauty and scientific interest, their virtues are few. Not so with the eucalypts. Give them a fair showing of place and climate, and they will thrive and enrich their environment. This tree has the hardiness of the ancient; it also has virtues which will enlarge the comforts and lengthen the days of men. As when some beneficent art, once enjoyed by a former people, has been lost, and, long known only in tradition, has been rediscovered and revived, and men are again enlivened with hope, so is the possession by the modern world of this ancient tree.

INTRODUCTION AND SUCCESSION OF VERTEBRATE LIFE IN AMERICA.[1]

By Professor O. C. MARSH.

[CONCLUDED FROM MARCH NUMBER.]

IT remains now to consider the highest group of the animal kingdom, the class *Mammalia*, which includes man. Of the existence of this class before the Trias we have no evidence, either in this country or in the Old World, and it is a significant fact that, at essentially the same horizon in each hemisphere, similar low forms of mammals make their appearance. Although only a few incomplete specimens have been discovered, they are characteristic and well preserved, and all are apparently Marsupials, the lowest mammalian group which we know in this country, living or fossil. The American Triassic mammals are known at present only from two small lower jaws, on which is based the genus *Dromatherium*, supposed to be related to the insect-eating *Myrmecobius*, now living in Australia.

Although the Jura of Europe has yielded other similar mammals, we have as yet none of this class from that formation; while, from rocks of Cretaceous age, no mammals are known in any part of the world. This is especially to be regretted, as it is evidently to the Cretaceous that we must look for the first representatives of many of our present groups of mammals, as well as for indications of their more ancient lineage. That some discovery of this nature from the Cretaceous is near at hand, I cannot doubt, when I consider what the last few years have brought to light in the Eocene.

In the lowest Tertiary beds of this country a rich mammalian fauna suddenly makes its appearance, and, from that time through the age of mammals to the present, America has been constantly occupied by this type of life in the greatest diversity of form. Fortunately, a nearly continuous record of this life, as preserved, is now accessible to us, and insures great additions to our knowledge of the genealogy of mammals, and perhaps the solution of more profound problems. Before proceeding to discuss in detail American fossil *Mammalia*, it is important to define the divisions of time indicated in our Tertiary and Post-Tertiary deposits, as these in many cases mark successive stages in the development of the mammals.

The boundary-line between the Cretaceous and Tertiary in the region of the Rocky Mountains has been much in dispute during the last few years, mainly in consequence of the uncertain geological bearings of the fossil plants found near this horizon. The accompanying

[1] An address delivered before the American Association for the Advancement of Science, at Nashville, Tenn., August 30, 1877, by Prof. O. C. Marsh, Vice-President.

invertebrate fossils have thrown little light on the question, which is essentially whether the great Lignite series of the West is uppermost Cretaceous or lowest Eocene. The evidence of the numerous vertebrate remains is, in my judgment, decisive, and in favor of the former view.

This brings up an important point in paleontology, one to which my attention was drawn several years since, namely: the comparative value of different groups of fossils in marking geological time. In examining the subject with some care, I found that, for this purpose, plants, as their nature indicates, are most unsatisfactory witnesses; that invertebrate animals are much better; and that vertebrates afford the most reliable evidence of climatic and other geological changes. The subdivisions of the latter group, moreover, and in fact all forms of animal life, are of value in this respect, mainly according to the perfection of their organization or zoölogical rank. Fishes, for example, are but slightly affected by changes that would destroy reptiles or birds, and the higher mammals succumb under influences that the lower forms pass through in safety. The more special applications of this general law, and its value in geology, will readily suggest themselves.

The evidence offered by fossil remains is, in the light of this law, conclusive, that the line, if line there be, separating our Cretaceous from the Tertiary, must at present be drawn where the Dinosaurs and other Mesozoic vertebrates disappear, and are replaced by the mammals, henceforth the dominant type.[1]

The Tertiary of Western America comprises the most extensive series of deposits of this age known to geologists, and important breaks in both the rocks and the fossils separate it into three well-marked divisions. These natural divisions are not the exact equivalents of the Eocene, Miocene, and Pliocene of Europe, although usually so considered, and known by the same names; but, in general, the fauna of each appears to be older than that of its corresponding representative in the other hemisphere; an important fact, not hitherto recognized. This partial resemblance of our extinct faunas to others in regions widely separated, where the formations are doubtless somewhat different in geological age, is precisely what we might expect, if, as was probable, the main migrations took place from this continent. It is better at once to recognize this principle, rather than attempt to bring into exact parallelism formations that were not strictly contemporaneous.

The fresh-water Eocene deposits of our Western Territories, which are in the same region at least two miles in vertical thickness, may be separated into three distinct subdivisions. The lowest of these, resting unconformably on the Cretaceous, has been termed the Vermilion Creek, or Wahsatch, group. It contains a well-marked mammalian

[1] *See* Frontispiece Section, March number.

fauna, the largest and most characteristic genus of which is the ungulate *Coryphodon*, and hence I have called these deposits the Coryphodon beds. The middle Eocene strata, which have been termed the Green River and Bridger Series, may be designated as the Dinoceras beds, as the gigantic animals of this order are only found here. The uppermost Eocene, or the Uintah group, is especially well characterized by large mammals of the genus *Diplacodon*, and hence may be termed the Diplacodon beds. The fauna of each of these three subdivisions was essentially distinct, and the fossil remains of each were entombed in different and successive ancient lakes. It is important to remember that these Eocene lake-basins all lie between the Rocky Mountains on the east and the Wahsatch Range on the west, or along the high central plateau of the continent. As these mountain chains were elevated, the inclosed Cretaceous sea, cut off from the ocean, gradually freshened, and formed these extensive lakes, while the surrounding land was covered with a luxuriant tropical vegetation, and with many strange forms of animal life. As the upward movement of this region continued, these lake-basins, which for ages had been filling up, preserving in their sediments a faithful record of Eocene life-history, were slowly drained by the constant deepening of the outflowing rivers, and they have since remained essentially dry land.

The Miocene lake-basins are on the flanks of this region, where only land had been since the close of the Cretaceous. These basins contain three faunas, nearly or quite distinct. The lowest Miocene, which is only found east of the Rocky Mountains, alone contains the peculiar mammals known as the *Brontotheridæ*, and these deposits may be called the Brontotherium beds. The strata next above, which represent the middle Miocene, have as their most characteristic fossil the genus *Oreodon*, and are known as the Oreodon beds. The upper Miocene, which occurs in Oregon, is of great thickness, and from one of its most important fossils, *Miohippus*, may be designated as the Miohippus Series. The climate here during this period was warm temperate.

Above the Miocene, east of the Rocky Mountains and on the Pacific coast, the Pliocene is well developed, and is rich in vertebrate remains. The strata rest unconformably on the Miocene, and there is a well-marked faunal change at this point, modern types now first making their appearance. For these reasons, we are justified in separating the Miocene from the Pliocene at this break; although in Europe, where no marked break exists, the line seems to have been drawn at a somewhat higher horizon. Our Pliocene forms essentially a continuous series, although the upper beds may be distinguished from the lower by the presence of a true *Equus*, and some other existing genera. The Pliocene climate was similar to that of the Miocene. The Post-Pliocene beds contain many extinct mammals, and may thus be separated from recent deposits.

Returning now to our subject from this geological digression—which will hardly be deemed unprofitable, since I have given you in few words the results of a great deal of my own hard mountain work—let us consider the Tertiary mammals, as we know them from the remains already discovered, and attempt to trace the history of each order down to the present time. We have seen that a single small Marsupial, from the Trias, is the only mammal found in all the American rocks below the Eocene; and yet in beds of this age, immediately over the Chalk, fossil mammals of many different kinds abound.

The Marsupials, strange to say, are here few in number, and diminutive in size; and have as yet been identified only by fragmentary specimens, and most of them are too imperfect for accurate description. In the higher Eocene deposits, this group is more abundant, but still represented by small animals, most of them insectivorous, or carnivorous in habit, like the existing opossum. From the Miocene and Pliocene, no remains of Marsupials have been described. From the Post-Tertiary, only specimens nearly allied to those now living are known, and most of these were found in the caves of South America.

The Edentate[1] Mammals are evidently an American type, and on this continent attained a great development in numbers and size. No Eocene Edentates have been found here, and, although their discovery in this formation has been announced, the identification proves to have been erroneous. In the Miocene of the Pacific coast, a few fossils have been discovered which belong to animals of this group, and to the genus *Moropus*. There are two species, one about as large as a tapir, and the other nearly twice that size. This genus is the type of a distinct family, the *Moropodidæ*. In the lower Pliocene above, well-preserved remains of Edentates of very large size have been found at several widely-separated localities in Idaho and California. These belong to the genus *Morotherium*, of which two species are known. East of the Rocky Mountains, in the lower Pliocene of Nebraska, a large species apparently of the genus *Moropus* has been discovered. The horizon of these later fossils corresponds nearly with beds in Europe that have been called Miocene. In the Post-Pliocene of North America, gigantic Edentates were very numerous and widely distributed, but all disappeared with the close of that period. These forms were essentially huge sloths, and the more important genera were *Megatherium*, *Mylodon*, and *Megalonyx*. The genera *Megalocnus* and *Myomorphus* have been found only in Cuba.

In South America, during the Pliocene or Post-Pliocene, enormous Edentates were still more abundant, and their remains are usually in

[1] The Edentates are an order of Mammals, in which the teeth are imperfect or wanting. The teeth when present are without enamel, or true roots. This order includes the sloths, armadilloes, ant-eaters, etc.

such perfect preservation as to suggest a very recent period for their extinction. The Sloth tribe is represented by the huge *Mylodon*, *Megatherium*, *Megalonyx*, *Cœlodon*, *Ochotherium*, *Gnathopis*, *Lestodon*, *Scelidotherium*, and *Sphænodon;* and among the Armadilloes were *Chlamydotherium*, *Eurydon*, *Glyptodon*, *Heterodon*, *Pachytherium*, and *Schistopleurum*. *Glossotherium*, another extinct genus, is supposed to be allied to the Ant-Eaters.

It is frequently asserted, and very generally believed, that the large number of huge *Edentata* which lived in North America during the Post-Pliocene were the results of an extensive migration from South America soon after the elevation of the Isthmus of Panama, near the close of the Tertiary. No conclusive proof of such migration has been offered, and the evidence, it seems to me, so far as we now have it, is directly opposed to this view. No undoubted Tertiary Edentates have yet been discovered in South America, while we have at least two species in our Miocene, and, during the deposition of our lower Pliocene, large individuals of this group were not uncommon as far north as the forty-third parallel of latitude, on both sides of the Rocky Mountains. In view of these facts, and others which I shall lay before you, it seems more natural to conclude, from our present knowledge, that the migration, which no doubt took place, was from north to south. The Edentates, finding thus in South America a congenial home, flourished greatly for a time, and, although the larger forms are now all extinct, diminutive representatives of the group still inhabit the same region.

The *Cetacea*[1] first appear in the Eocene, as in Europe, and are comparatively abundant in deposits of this age on the Atlantic coast. The most interesting remains of this order, yet found, belong to the *Zeuglodontidæ*, which are carnivorous whales, and the only animals of the order with teeth implanted by two roots. The principal genera of this family are *Zeuglodon* and *Squalodon*, the former genus being represented by gigantic forms, some of which were seventy feet in length. The genus *Saurocetes*, which includes some small animals of this group, has been found in South America. The Dolphin family (*Delphinidæ*) are well represented in the Miocene, both on the Atlantic and Pacific coast. The best-known genus is *Priscodelphinus*, of which several species have been described. Several other generic names which have been applied to fragments need not here be enumerated. In none of the Tertiary species of this family were the cervical vertebræ anchylosed. The Sperm Whales (*Catodontidæ*) were also abundant throughout the Tertiary, and with them, in the earlier beds, various Ziphioid forms have been found. The toothless *Balænidæ* are only known with certainty as fossils from the later Tertiary and more recent deposits.

[1] *Cetacea*, an order of marine mammals which includes among its living representatives the whales, dolphins, porpoises, narwhal, etc.

The Sirenians,[1] which appear first in the Eocene of the Old World, occur in the Miocene of our eastern coast, and throughout the later Tertiary. The specimens described have all been referred to the genus *Manatus*, and seem closely related to our living species. In the Tertiary of Jamaica, a skull has been found which indicates a new genus, *Prorastomus*, also allied to the existing manatee. The genus *Rhytina*, once abundant on our Northwest coast, has recently become extinct.

The Ungulates[2] are the most abundant mammals in the Tertiary, and the most important, since they include a great variety of types, some of which we can trace through their various changes down to the modified forms that represent them to-day. Of the various divisions in this comprehensive group, the Perissodactyle, or odd-toed Ungulates, are evidently the oldest, and throughout the Eocene are the prevailing forms. Although all of the Perissodactyles of the earlier Tertiary are more or less generalized, they are still quite distinct from the Artiodactyles, even at the base of the Eocene. One family, however, the *Coryphodontidæ*, which is well represented at this horizon, both in America and Europe, although essentially Perissodactyle, possesses some characters which point to a primitive Ungulate type from which the present orders have been evolved. Among these characters are the diminutive brain, which in size and form approaches that of the reptiles, and also the five-toed feet, from which all the various forms of the mammalian foot have been derived. Of this family, only a single genus, *Coryphodon* (*Bathmodon*), is known, but there were several distinct species. They were the largest mammals of the lower Eocene, some exceeding in size the existing tapirs.

In the middle Eocene, west of the Rocky Mountains, a remarkable group of Ungulates makes its appearance. These animals nearly equaled the elephant in size, but had shorter limbs. The skull was armed with two or three pairs of horn-cores, and with enormous canine tusks. The brain was proportionally smaller than in any other land mammal. The feet had five toes, and resembled in their general structure those of *Coryphydon*, thus indicating some affinity with that genus. These mammals resemble in some respects the Perissodactyles, and in others the Proboscidians, yet differ so widely from any known Ungulates, recent or fossil, that they must be regarded as forming a distinct order, the *Dinocerata*. Only three genera are known, *Dinoceras*, *Tinoceras*, and *Uintatherium*, but quite a number of species have been described. During the later part of the middle Eocene these animals were very abundant for a short time, and then be-

[1] *Sirenia*, an order of aquatic mammals represented at present only by the manatee and dugong.

[2] *Ungulata*. As now used, this term is employed to designate that order of mammals which contains the *Artiodactyla*, or even-toed, and the *Perissodactyla*, or odd-toed, mammals with hoofs. It thus includes, among the former, the camels, giraffe, bovines, antelopes, deer, musks, swine, and hippopotami; and, among the latter, the horses, rhinoceroses, and tapirs.

came extinct, leaving apparently no successor, unless possibly we have in the Proboscidians their much-modified descendants. Their genetic connection with the Coryphodonts is much more probable, in view of what we now know of the two groups.

Besides these peculiar mammals, which are extinct, and mainly of interest to the biologist, there were others in the early Tertiary which remind us of those at present living around us. When a student in Germany some twelve years ago, I heard a world-renowned Professor of Zoölogy gravely inform his pupils that the horse was a gift of the Old World to the New, and was entirely unknown in America until introduced by the Spaniards. After the lecture I asked him whether no earlier remains of horses had been found on this continent, and was told in reply that the reports to that effect were too unsatisfactory to be presented as facts in science. This remark led me, on my return, to examine the subject myself, and I have since unearthed, with my own hands, not less than thirty distinct species of the horse tribe in the Tertiary deposits of the West alone; and it is now, I think, generally admitted that America is, after all, the true home of the horse.

I can offer you no better illustration than this of the advance vertebrate paleontology has made during the last decade, or of the important contributions to this progress which our Rocky Mountain region has supplied.

The oldest representative of the horse, at present known, is the diminutive *Eohippus*, from the lower Eocene. Several species have been found, all about the size of a fox. Like most of the early mammals, these Ungulates had forty-four teeth, the molars with short crowns, and quite distinct in form from the premolars. The ulna and the fibula were entire and distinct, and there were four well-developed toes, and a rudiment of another on the fore-feet, and three toes behind. In the structure of the feet, and in the teeth, the *Eohippus* indicates unmistakably that the direct ancestral line to the modern horse has already separated from the other Perissodactyles. In the next higher division of the Eocene, another genus, *Orohippus*, makes its appearance, replacing *Eohippus*, and showing a greater, although still distant, resemblance to the Equine type. The rudimentary first digit of the fore-foot has disappeared, and the last premolar has gone over to the molar series. *Orohippus* was but little larger than *Eohippus*, and in most other respects very similar. Several species have been found in the same horizon with *Dinoceras*, and others lived during the upper Eocene with *Diplacodon*, but none later.[1]

Near the base of the Miocene, in the Brontotherium beds, we find a third closely-allied genus, *Mesohippus*, which is about as large as a

[1] Since this address was delivered, I have found in the Diplacodon beds a new genus of Equines (*Epihippus*), which is larger than *Orohippus*, and has the same number of toes, but has two premolar teeth like the molars.—O. C. M.

sheep, and one stage nearer the horse. Three are only three toes and a rudimentary splint bone in the fore feet, and three toes behind. Two of the premolar teeth are quite like the molars. The ulna is no longer distinct, or the fibula entire, and other characters show clearly that the transition is advancing. In the upper Miocene, *Mesohippus* is not found, but in its place a fourth form, *Miohippus*, continues the line. This genus is near the *Anchitherium* of Europe, but presents several important differences. The three toes in each foot are more nearly of a size, and a rudiment of the fifth metacarpal bone is retained. All the known species of this genus are larger than those of *Mesohippus*, and none pass above the Miocene.

The genus *Protohippus*, of the lower Pliocene, is yet more equine, and some of its species equaled the ass in size. There are still three toes on each foot, but only the middle one, corresponding to the single toe of the horse, comes to the ground. This genus resembles most nearly the *Hipparion* of Europe. In the Pliocene, we have the last stage of the series before reaching the horse, in the genus *Pliohippus*, which has lost the small hooflets, and in other respects is very equine. Only in the upper Pliocene does the true *Equus* appear, and complete the genealogy of the horse, which in the Post-Tertiary roamed over the whole of North and South America, and soon after became extinct. This occurred long before the discovery of the continent by Europeans, and no satisfactory reason for the extinction has yet been given. Besides the characters I have mentioned, there are many others, in the skeleton, skull, teeth, and brain, of the forty or more intermediate species, which show that the transition from the Eocene *Eohippus* to the modern *Equus* has taken place in the order indicated; and I believe the specimens now at New Haven will demonstrate the fact to any anatomist. They certainly carried prompt conviction to the first of anatomists, who was the honored guest of the Association a year ago, whose genius had already indicated the later genealogy of the horse in Europe, and whose own researches so well qualified him to appreciate the evidence here laid before him. Did time permit, I might give you at least a probable explanation of this marvelous transition, but justice to the comrades of the horse in his long struggle for existence demands that some notice of their efforts should be placed on record.

Besides the horse and his congeners, the only existing Perissodactyles are the rhinoceros and tapir. The last is the oldest type, but the rhinoceros had near allies throughout the Tertiary; and, in view of the continuity of the equine line, it is well worth while to attempt to trace his pedigree. At the bottom of the Eocene, in our Western lake-basins, the tapiroid genus *Helaletes* is found, represented by numerous small mammals hardly larger than the diminutive horses of that day. In the following epoch of the Eocene, the closely-allied *Hyrachyus* was one of the most abundant animals. This genus was nearly related to the *Lophiodon* of Europe, and in its teeth and skele-

ton strongly resembled the living tapir, whose ancestry, to this point, seems to coincide with that of the rhinoceros we are considering. Strangely enough, the rhinoceros line, before it becomes distinct, separates into two branches. In the upper part of the Dinoceras beds we have the genus *Colonoceras*, which is really a *Hyrachyus* with a transverse pair of very rudimentary horn-cores on the nasal bones. In the lower Miocene west of the Rocky Mountains this line seems to pass on through the genus *Diceratherium*, and in the higher Miocene this genus is well represented. Some of the species nearly equaled in size the existing rhinoceros, which *Diceratherium* strongly resembled. The main difference between them is a most interesting one. The rudimentary horn-cores on the nasals, seen in *Colonoceras*, are in *Diceratherium* developed into strong bony supports for horns, which were placed transversely, as in the ruminants, and not on the median line, as in all existing forms of rhinoceros. In the Pliocene of the Pacific coast, a large rhinoceros has been discovered, which may be a descendant of *Diceratherium;* but, as the nasal bones have not been found, we must wait for further evidence on this point. Returning now to the other branch of the rhinoceros group, which left their remains mainly east of the Rocky Mountains, we find that all the known forms are hornless. The upper Eocene genus, *Amynodon*, is the oldest known rhinoceros, and by far the most generalized of the family. The premolars are all unlike the molars; the four canines are of large size, but the inner incisor in each jaw is lost in the fully adult animal. The nasals were without horns. There were four toes in front, and three behind. The genus *Hyracodon*, of the Miocene, which is essentially a rhinoceros, has a full set of incisor and canine teeth; and the molars are so nearly like those of its predecessor, *Hyrachyus*, that no one will question the transformation of the older into the newer type. *Hyracodon*, however, appears to be off the true line, for it has but three toes in front. In the higher Miocene beds, and possibly with *Hyracodon*, occurs a larger rhinoceros, which has been referred to the genus *Aceratherium*. This form has lost the canine and one incisor above, and two incisors below. In the Pliocene are several species closely related, and of large size. Above the Pliocene in America, no vestiges of the rhinoceros have been found; and our American forms, doubtless, became extinct at the close of this period.

The tapir is clearly an old American type; and we have seen that, in the Eocene, the genera *Helaletes* and *Hyrachyus* were so strongly tapiroid in their principal characters that the main line of descent probably passed through them. It is remarkable that the Miocene of the West, so greatly developed as it is on both sides of the Rocky Mountains, should have yielded but a few fragments of tapiroid mammals; and the same is true of the Pliocene of that region. In the Miocene of the Atlantic coast, too, only a few imperfect specimens have been found. These forms all apparently belong to the genus

Tapiravus, although most of them have been referred to *Lophiodon*—a lower Eocene type. In the Post-Tertiary, a true *Tapirus* was abundant; and its remains have been found in various parts of North America. The line of descent, although indistinct through the middle and upper Tertiary, was doubtless continuous in America; and several species exist at present from Mexico southward. It is worthy of notice that the species north of the Isthmus of Panama appear all to be generically distinct from those of South America.

In addition to these three Perissodactyle types, which, as the fittest, have alone survived, and whose lineage I have endeavored to trace, there were many others in early Tertiary times. Some of these disappeared with the close of the Eocene, while others continued, and assumed strange specialized shapes in the Miocene, before their decline and extinction. One series of the latter deserves especial mention, as it includes one of the most interesting families of our extinct animals. Among the large mammals in the lower Eocene is *Limnohyus*, a true Perissodactyle, but only known here from fragments of the skeleton. In the next higher beds, this genus is well represented, and with it is found a nearly allied form, *Palæosyops*. In the upper Eocene, both have left the field, and the genus *Diplacodon*, a very near relative, holds the supremacy. The line seems clear through these three genera, but on crossing the break into the Miocene, we have apparently, as next of kin, the huge *Brontotheridæ*. These strange beasts show in their dentition and some other characters the same transition steps beyond the *Diplacodon*, which that genus had made beyond *Palæosyops*. The *Brontotheridæ* were nearly as large as the elephant, but had much shorter limbs. The skull was elongated, and had a transverse pair of large horn-cores on the maxillaries, in front of the orbits, like the middle pair in *Dinoceras*. There were four toes in front and three behind, and the feet were similar to those of the rhinoceros. There are four genera in this group, *Brontotherium; Diconodon; Menodus* (*Titanotherium*); and *Megacerops*, which have been found only in the lowest Miocene, east of the Rocky Mountains.

In the higher Miocene beds of Oregon, an allied genus, *Chalicotherium*, makes its appearance. It is one stage further on in the transition, and perhaps a descendant of the *Brontotheridæ;* but here, so far as now known, the line disappears. It is a suggestive fact that this genus has now been found in Western America, China, India, Greece, Germany, and France, indicating thus, as I believe, the path by which many of our ancient mammals helped to people the so-called Old World.

The Artiodactyles,[1] or even-toed Ungulates, are the most abundant

[1] *Artiodactyla*, a sub-order of the *Ungulata*, in which the third and fourth digits are nearly equally developed, and their ungual phalanges are flattened on their contiguous sides, so that together they constitute a symmetrical form. The axis, or middle line, of the whole foot lies between the third and fourth digits.

of the larger mammals now living; and the group dates back at least to the lowest Eocene. Of the two well-marked divisions of this order, the Bunodonts[1] and the Selenodonts,[2] as happily defined by Kowalevsky, the former is the older type, which must have separated from the Perissodactyle line after the latter had become differentiated from the primitive Ungulate. In the Coryphodon beds of New Mexico occurs the oldest Artiodactyle yet found, but it is at present known only from fragmentary specimens. These remains are clearly Suilline in character, and belong to the genus *Eohyus*. In the beds above, and possibly even in the same horizon, the genus *Helohyus* is not uncommon, and several species are known. The molar teeth of this genus are very similar to those of the Eocene *Hyracotherium*, of Europe, which is supposed to be a Perissodactyle, while *Helohyus* certainly is not, but apparently a true lineal ancestor of the existing pigs. In every vigorous primitive type which was destined to survive many geological changes, there seems to have been a tendency to throw off lateral branches, which became highly specialized and soon died out, because they are unable to adapt themselves to new conditions. The narrow path of the persistent Suilline type, throughout the whole Tertiary, is strewed with the remains of such ambitious offshoots; while the typical pig, with an obstinacy never lost, has held on in spite of catastrophes and evolution, and still lives in America to-day. In the lower Eocene, we have in the genus *Parahyus* apparently one of these short-lived, specialized branches. It attained a much larger size than the true lineal forms, and the number of its teeth was reduced. In the Dinoceras beds, or middle Eocene, we have still, on or near the true line, *Helohyus*, which is the last of the series known from the American Eocene. All these early Suillines, with the possible exception of *Parahyus*, appear to have had at least four toes of usable size.

In the lower Miocene, we find the genus *Perchœrus*, seemingly a true Suilline, and with it remains of a larger form, *Elotherium*, are abundant. The latter genus occurs in Europe in nearly the same horizon, and the specimens known from each continent agree closely in general characters. The name *Pelonax* has been applied erroneously to some of the American forms; but the specimens on which it was based clearly belong to *Elotherium*. This genus affords another example of the aberrant Suilline offshoots, already mentioned. Some of the species were nearly as large as a rhinoceros, and in all there were but two serviceable toes; the outer digits, seen in living animals of this group, being represented only by small rudiments concealed beneath the skin. In the upper Miocene of Oregon, Suillines are abundant, and almost all belong to the genus *Thinohyus*, a near ally of

[1] *Bunodont* (hill-tooth); hence, teeth the crowns of which are composed of rounded tubercles.

[2] *Selenodont* (moon-tooth); teeth which have the crowns marked by crescents.

the modern peccary (*Dicotyles*), but having a greater number of teeth, and a few other distinguishing features. In the Pliocene, Suillines are still numerous, and all the American forms yet discovered are closely related to *Dicotyles*. The genus *Platygonus* is represented by several species, one of which was very abundant in the Post-Tertiary of North America, and is apparently the last example of a side branch, before the American Suillines culminate in existing peccaries. The feet in this species are more specialized than in the living forms, and approach some of the peculiar features of the ruminants; as, for example, a strong tendency to coalescence in the metapodial bones. The genus *Platygonus* became extinct in the Post-Tertiary, and the later and existing species are all true peccaries.

No authenticated remains of the genera *Sus*, *Porcus*, *Phacochœrus*, or the allied *Hippopotamus*, the Old World Suillines, have been found in America, although several announcements to that effect have been made.

In the series of generic forms between the lower Eocene *Eohyus* and the existing *Dicotyles*, which I have very briefly discussed, we have apparently the ancestral line ending in the typical American Suillines. Although the demonstration is not yet as complete as in the lineage of the horse, this is not owing to want of material, but rather to the fact that the actual changes which transformed the early Tertiary pig into the modern peccary were comparatively slight, so far as they are indicated in the skeletons preserved, while the lateral branches were so numerous as to confuse the line. It is clear, however, that from the close of the Cretaceous to the Post-Tertiary the Bunodont Artiodactyles were especially abundant on this continent, and only recently have approached extinction.

The Selenodont division of the Artiodactyles is a more interesting group and, so far as we now know, makes its first appearance in the upper Eocene of the West, although forms, apparently transitional, between it and the Bunodonts occur in the Dinoceras beds, or middle Eocene. These belong to the genus *Homacodon*, which is very nearly allied to *Helohyus*, and but a single step away from this genus toward the Selenodonts. By a fortunate discovery, a nearly complete skeleton of this rare intermediate form has been brought to light, and we are thus enabled to define its characters. Several species of *Homacodon* are known, all of small size. This primitive Selenodont had forty-four teeth, which formed a nearly continuous series.

The molar teeth are very similar to those of *Helohyus*, but the cones on the crowns have become partially triangular in outline, so that, when worn, the Selenodont pattern is clearly recognizable. The first and second upper molars, moreover, have three distinct posterior cusps, and two in front; a peculiar feature, which is seen also in the European genera *Dichobune* and *Cainotherium*. There were four toes on each foot, and the metapodial bones were distinct. The type spe-

cies of this genus was about as large as a cat. With *Helohyus*, this genus forms a well-marked family, the *Helohyidæ*.

In the *Diplacodon* horizon of the upper Eocene, the Selenodont dentition is no longer doubtful, as it is seen in most of the *Artiodactyla* yet found in these beds. These animals are all small, and belong to at least three distinct genera. One of these, *Eomeryx*, closely resembles *Homacodon* in most of its skeleton, and has four toes, but its teeth show well-marked crescents, and a partial transition to the teeth of *Hyopotamus*, frum the Eocene of Europe. With this genus is another, *Parameryx*, also closely allied to *Homacodon*, but apparently a straggler from the true line, as it has but three toes behind. The most pronounced Selenodont in the upper Eocene is the *Oromeryx*, which genus appears to be allied to the existing Deer family, or *Cervidæ*, and if so is the oldest known representative of the group. These facts are important, as it has been supposed, until very recently, that our Eocene contained no even-hoofed mammals.

In the lowest Miocene of the West, no true crescent-toothed *Artiodactyla* have as yet been identified, with the exception of a single species of *Hyopotamus;* but, in the overlying beds of the middle Miocene, remains of the *Oreodontidæ* occur in such vast numbers as to indicate that these animals must have lived in large herds around the borders of the lake-basins in which their remains have been entombed. These basins are now the denuded deserts so well termed *Mauvaises Terres* by the early French trappers. The least specialized, and apparently the oldest, genus of this group is *Agriochœrus*, which so nearly resembles the older *Hyopotamus*, and the still more ancient *Eomeryx*, that we can hardly doubt that they all belonged to the same ancestral line. The typical Oreodonts are the genera *Oreodon* and *Eporeodon*, which have been aptly termed by Leidy ruminating hogs. They had forty-four teeth, and four well-developed toes on each foot. The true Oreodons, which were most numerous east of the Rocky Mountains, were about as large as the existing peccary, while *Eporeodon*, which was nearly twice this size, was very abundant in the Miocene of the Pacific slope.

In the succeeding Pliocene formation, on each side of the Rocky Mountains, the genus *Merychyus* is one of the provailing forms, and continues the line on from the Miocene, where the true Oreodons became extinct. Beyond this, we have the genus *Merychochœrus*, which is so nearly allied to the last that they would be united by many naturalists. With the close of the Pliocene, this series of peculiar ruminants abruptly terminates, no member surviving until the Post-Tertiary, so far as known.

A most interesting line, that leading to the camels and llamas, separates from the primitive Selenodont branch in the Eocene, probably through the genus *Parameryx*. In the Miocene, we find in *Pœbrotherium* and some nearly allied forms unmistakable indications

that the Cameloid type of ruminant had already become partially specialized, although there is a complete series of incisor teeth, and the metapodial bones are distinct. In the Pliocene, the camel tribe was, next to the horses, the most abundant of the larger mammals. The line is continued through the genus *Procamelus*, and perhaps others, and in this formation the incisors first begin to diminish, and the metapodials to unite. In the Post-Tertiary we have a true *Auchenia*, represented by several species, and others in South America, where the alpacas and llamas still survive. From the Eocene almost to the present time, North America has been the home of vast numbers of the *Camelidæ*, and there can be little doubt that they originated here, and migrated to the Old World.

Returning once more to the upper Eocene, we find another line of descent starting from *Oromeryx*, which, as we have seen, had apparently then just become differentiated from the older Bunodont type. Throughout the middle and upper Miocene, this line is carried forward by the genus *Leptomeryx* and its near allies, which resemble so strongly the Pliocene *Cervidæ* that they may fairly be regarded as their probable progenitors. Possibly some of these forms may be related to the *Tragulidæ*, but at present the evidence is against it.

The deer family has representatives in the upper Miocene of Europe, which contains fossils strongly resembling the fauna of our lower Pliocene, a fact always to be borne in mind in comparing the horizon of any group in the two continents. Several species of *Cervidæ*, belonging to the genus *Cosoryx*, are known from the lower Pliocene of the West, and all have very small antlers, divided into a single pair of tynes. The statement recently published, that most of these antlers had been broken during the life of the animals, is unsupported by any evidence, and is erroneous. These primitive deer do not have the orbit closed behind, and they have all the four metapodial bones entire, although the second and fifth are very slender. In the upper Pliocene, a true *Cervus* of large size has been discovered. In the Post-Tertiary, *Cervus*, *Alces*, and *Tarandus*, have been met with, the latter far south of its present range. In the caves of South America, remains of *Cervus* have been found, and also two species of antelopes, one referred to a new genus, *Leptotherium*.

The hollow-horned ruminants, in this country, appear to date back no further than to the lower Pliocene, and here only two species of *Bison* have as yet been discovered. In the Post-Tertiary this genus was represented by numerous individuals and several species, some of large size. The musk-ox (*Ovibos*) was not uncommon during some parts of this epoch, and its remains are widely distributed.

No authentic fossil remains of true sheep, goats, or giraffes, have as yet been found on this continent.

The Proboscidians,[1] which are now separated from the typical

[1] *Proboscidea*, the mammalian order which contains the elephants, and extinct mastodon and mammoth.

Ungulates as a distinct order, make their first appearance in North America in the lower Pliocene, where several species of *Mastodon* have been found. This genus occurs, also, in the upper Pliocene, and in the Post-Tertiary; although some of the remains attributed to the latter are undoubtedly older. The Pliocene species all have a band of enamel on the tusks, and some other peculiarities observed in the oldest mastodons of Europe, which are from essentially the same horizon. Two species of this genus have been found in South America, in connection with the remains of extinct llamas and horses. The genus *Elephas* is a later form, and has not yet been identified in this country below the upper Pliocene, where one gigantic species was abundant. In the Post-Pliocene, remains of this genus are numerous. The hairy mammoth of the Old World (*Elephas primigenius*) was once abundant in Alaska, and great numbers of its bones are now preserved in the frozen cliffs of that region. This species does not appear to have extended east of the Rocky Mountains, or south of the Columbia River, but was replaced there by the American elephant, which preferred a milder climate. Remains of the latter have been met with in Canada, throughout the United States, and in Mexico. The last of the American mastodons and elephants became extinct in the Post-Tertiary.

The order *Toxodontia* includes two very peculiar genera, *Toxodon* and *Nesodon*, which have been found in the Post-Tertiary deposits of South America. These animals were of huge size, and possessed such mixed characters that their affinities are a matter of considerable doubt. They are thought to be related to the Ungulates, Rodents, and Edentates; but, as the feet are unknown, this cannot at present be decided.

Macrauchenia and *Homalodontotherium* are two other peculiar genera from South America, now extinct, the exact affinities of which are uncertain. *Anoplotherium* and *Palæotherium*, so abundant in Europe, have not been found in our North American Tertiary deposits, although reported from South America.

Perhaps the most remarkable mammals yet found in America are the *Tillodontia*, which are comparatively abundant in the lower and middle Eocene. These animals seem to combine the characters of several different groups, viz., the Carnivores, Ungulates, and Rodents. In the genus *Tillotherium*, the type of the order, and of the family *Tillotheridæ*, the skull resembles that of the bears; the molar teeth are of the ungulate type, while the large incisors are very similar to those of Rodents. The skeleton resembles that of the Carnivores, but the scaphoid and lunar bones are distinct, and there is a third trochanter on the femur. The feet are plantigrade, and each had five digits, all with long, pointed claws. In the allied genus *Stylinodon*, which belongs to a distinct family, the *Stylinodontidæ*, all the teeth were rootless. Some of these animals were as large as a tapir. The genus

Dryptodon has been found only in the *Coryphodon* beds of New Mexico, while *Tillotherium* and *Stylinodon* occur in the middle Eocene of Wyoming. *Anchippodus* probably belongs to this group, which may perhaps include some other forms that have been named from fragmentary specimens.

The Rodents are an ancient type, and their remains are not unfrequently disinterred in the strata of our lowest fresh-water Eocene. The earliest known forms are, apparently, all related to the squirrels; and the most common genus is *Sciuravus*, which continued throughout the Eocene. A nearly allied form, which may prove to be the same, is *Paramys*, the species of which are larger than those of the older type. In the Dinoceras beds, the genus *Colonomys* is found, and the specimens preserved point to the *Muridæ* as the nearest living allies. A peculiar genus, *Apatemys*, which also occurs in the middle Eocene, has gliriform incisors; but the molars resemble those of Insectivores. All the Eocene Rodents known are of small size, the largest being about as large as a rabbit.

In the middle and upper Miocene lake-basins of the West, Rodents abound, but all are of moderate size. The hares first appear in the Oreodon beds, and continue in considerable numbers through the rest of the Tertiary and Post-Tertiary, to the present day. In these beds, the most common forms belong to the *Leporidæ*, and mainly to the genus *Palæolagus*. The Squirrel family is represented by *Ischyromys*, the *Muridæ* by the genus *Eumys*, and the beavers by *Palæocastor*. In the upper Miocene of Oregon, most of the same genera are found; and with them some peculiar forms, very unlike anything now living. One of these is the genus *Allomys*, possibly related to the flying-squirrels, but having molar teeth somewhat like those of the Ungulates. In the Pliocene, east and west of the Rocky Mountains, Rodents continue abundant; but most of them belong to existing genera. Among these are *Castor*, *Hystrix*, *Cynomys*, *Geomys*, *Lepus*, and *Hesperomys*. In the Post-Tertiary, the gigantic beaver, *Castoroides*, was abundant throughout most of North America. *Hydrochærus* has been found in South Carolina. In the caves of the island of Anguilla, in the West Indies, remains of large extinct Rodents, belonging to the *Chinchillidæ*, have been discovered.

The early Tertiary Rodents known from South America are the genera *Megamys*, *Theridromys*, and a large species referred to *Arvicola*. In Brazil, the Pliocene Rodents found are referred to the existing genera, *Cavia*, *Kerodon*, *Lagostomus*, *Ctenomys*, *Hesperomys*, *Oxymycterus*, *Arvicola*, and *Lepus*. A new genus, *Cardiodus*, described from this horizon, is a true rodent; but the peculiar *Typotherium*, which has been referred to this order by some authorities, has perhaps other affinities. In the Post-Tertiary, the Rodents were very abundant in South America, as they are at present. The species are, in most instances, distinct from those now living, but the genera are

nearly the same. The *Caviidæ* were especially numerous. *Cercolabes*, *Myopotamus*, and *Lagostomus*, are also found; and two extinct genera, *Phyllomys* and *Lonchophorus*.

The *Cheiroptera*, or bats, have not been found in this country below the middle Eocene, where two extinct genera, *Nyctilestes* and *Nyctitherium*, are each represented by numerous remains. These fossils all belong to small animals, and, so far as they have been investigated, show no characters of more than generic importance to distinguish them from the bats of to-day. No other members of this group are known from our Tertiary. In the Post-Tertiary, no extinct species of bats have been found in North America, but from the caves of Brazil quite a number have been reported. These all belong to genera still living in South America, and most of them to the family *Phyllostomidæ*.

The Insectivores[1] date back, in this country, at least to the middle Eocene. Here numerous remains occur, which have been described as belonging to this order, although it is possible that some of them were insect-eating Marsupials. The best-known genera are—*Hemiacodon*, *Centetodon*, *Talpavus*, and *Entomacodon;* all represented by animals of small size. In the Miocene, the bones of Insectivores are comparatively abundant, and the genera best determined are *Ictops* and *Leptictis*. A few specimens only have been found in the Pliocene and Post-Pliocene, most of them related to the moles. No extinct Insectivores are known from South America, and no member of the group exists there at present.

The *Carnivora*, or true flesh-eating animals, are an old type, well represented in the Eocene, and, as might be expected, these early forms are much less specialized than the living species. In the Coryphodon beds, the genus *Limnocyon*, allied to the *Pterodon* of the European Eocene, is abundant. Another genus, apparently distinct, is *Prototomus*, and several others have been named from fragmentary fossils. In the middle Eocene, Carnivores were still more numerous, and many genera have been discovered. One of these, *Limnofelis*, was nearly as large as a lion, and apparently allied to the cats, although the typical *Felidæ* seem not yet to have been differentiated. Another Carnivore, of nearly equal size, was *Orocyon*, which had short, massive jaws and broad teeth. *Dromocyon* and *Mesonyx* were large animals, allied to *Hyænodon*. The teeth were narrow, and the jaws long and slender. Among the smaller Carnivores were—*Vulpavus*, *Viverravus*, *Sinopa*, *Thinocyon*, and *Ziphacodon*.

In our Western Miocene, Carnivores are abundant, and make an approach to modern types. The *Felidæ* are well represented, the most interesting genus being *Machairodus*, which is not uncommon in the Oreodon beds on both sides of the Rocky Mountains. An

[1] *Insectivora*, that order of mammals which includes the existing moles, shrews, hedgehogs, etc.

allied genus is *Dinictis*, and several smaller cats are known from about the same horizon. The *Canidæ* are represented by *Amphicyon*, a European genus, and by several species of *Canis*, or a very nearly allied form. The peculiar genus *Hyænodon*, found also in Europe, and the type of a distinct family, is abundant in the Miocene east of the Rocky Mountains, but has not yet been found on the Pacific coast. In the Pliocene of both regions the *Canidæ* are numerous, and all apparently belong to the existing genus *Canis*. The genus *Machairodus* is still the dominant form of the cats, which are abundant, and for the most part belong to the genus *Felis*. The extinct *Leptarctus* is supposed to belong to the *Ursidæ*,[1] and, if so, is the oldest American representative of this family. In the Post-Pliocene, the extinct *Felidæ* include species nearly as large as a lion, and smaller forms very similar to those still living. Bears, raccoons, and weasels, have also been found.

In the Pliocene of South America, *Machairodus* represents the *Felidæ*, while the genera *Arctotherium* and *Hyænarctus* belong to the Bear family. Species of *Mustela* and *Canis* have also been found. In the caves of Brazil, the fauna of which is regarded as Post-Pliocene, one species of *Machairodus* is known, and one of *Synælurus*. *Canis* and *Icticyon*, still living in Brazil, and the extinct genus *Speothos*, represent the *Canidæ*. *Mephitis* and *Galictis*, among the weasels, were also present, and with them species of *Nasua* and *Arctotherium*.

We come now to the highest group of Mammals, the Primates, which includes the Lemurs, the Apes, and Man. This order has a great antiquity, and even at the base of the Eocene we find it represented by several genera belonging to the lower forms of the group. In considering these interesting fossils, it is important to have in mind that the Lemurs, which are usually regarded as Primates, although at the bottom of the scale, are found at the present day only in Madagascar and the adjacent regions of the globe. All the American monkeys, moreover, belong to one group, much above the Lemurs, while the Old World apes are higher still, and most nearly approach man.

In the lower Eocene of New Mexico we find a few representatives of the earliest known Primates, and among them are the genera *Lemuravus* and *Limnotherium*, each the type of a distinct family. These genera became very abundant in the middle Eocene of the West, and with them are found many others—all, however, included in the two families *Lemuravidæ* and *Limnotheridæ*. *Lemuravus* appears to have been most nearly allied to the Lemurs, and is the most generalized form of the Primates yet discovered. It had forty-four teeth, forming a continuous series above and below. The brain

[1] *Ursidæ*, the family including the bears, raccoons, etc.

was nearly smooth, and of moderate size. The skeleton most resembles that of the Lemurs. A nearly allied genus, belonging to the same family, is *Hyopsodus*. *Limnotherium* (*Tomitherium*) also is nearly related to the Lemurs, but shows some affinities with the South American marmosets. This genus had forty teeth. The brain was nearly smooth, and the cerebellum large, and placed mainly behind the cerebrum. The orbits are open behind, and the lachrymal foramen is outside the orbit. Other genera belonging to the *Limnotheridæ* are—*Notharctos*, *Hipposyus*, *Microsyops*, *Palæacodon*, *Thinolestes*, and *Telmatolestes*. Besides these, *Antiacodon* (*Anaptomorphus*), *Bathrodon*, and *Mesacodon*, should probably be placed in the same group. In the Diplacodon beds, or upper Eocene, no remains of Primates have yet been detected, although they will doubtless be found there. All the Eocene Primates known from American strata are low generalized forms, with characters in the teeth, skeleton, and feet, that suggest relationships with the Carnivores, and even with the Ungulates. These resemblances have led paleontologists to refer some imperfect specimens to both these orders.

In the Miocene lake-basins of the West, only a single species of the Primates has been identified with certainty. This was found in the Oreodon beds of Nebraska, and belongs to the genus *Laopithecus*, apparently related both to the *Limnotheridæ* and to some existing South American monkeys. In the Pliocene and Post-Pliocene of North America no remains of Primates have yet been found.

In the Post-Pliocene deposits of the Brazilian caves, remains of monkeys are numerous, and mainly belong to extinct species of *Callithrix*, *Cebus*, and *Jacchus*, all living South American genera. Only one extinct genus, *Protopithecus*, which embraced animals of large size, has been found in this peculiar fauna.

It is a noteworthy fact, that no traces of any Anthropoid apes, or indeed of any Old World monkeys, have yet been detected in America. Man, however, the highest of the Primates, has left his bones and his works from the arctic circle to Patagonia. Most of these specimens are clearly Post-Tertiary, although there is considerable evidence pointing to the existence of man in our Pliocene. All the remains yet discovered belong to the well-marked genus *Homo*, and apparently to a single species, at present represented by the American Indian.

In this rapid review of mammalian life in America, from its first known appearance in the Trias down to the present time, I have endeavored to state briefly the introduction and succession of the principal forms in each natural group. If time permitted, I might attempt the more difficult task of trying to indicate what relations these various groups may possibly bear to each other; what connection the ancient mammals of this continent have with the corresponding forms of the Old World; and, most important of all, what real progress

mammalian life has here made since the beginning of the Eocene. As it is, I can only say, in summing up, that the Marsupials are clearly the remnants of a very ancient fauna, which occupied this continent millions of years ago, and from which the other mammals were doubtless all derived, although the direct evidence of the transformation is wanting.

Although the Marsupials are nearly related to the still lower Monotremes, now living in the Australian region, we have as yet no hint of the path by which these two groups became separated from the inferior vertebrates. Neither have we to-day much light as to the genetic connection existing between Marsupials and the placental Mammalia, although it is possible that the different orders of the latter had their origin each from a separate group of the Marsupials.

The presence, however, of undoubted Marsupials in our lower and middle Eocene, some of them related to the genus *Didelphys*, although remotely, is important evidence as to the introduction of these animals into America. Against this, their supposed absence in our Miocene and Pliocene can have but limited weight, when taken in connection with the fact that they flourished in the Post-Tertiary, and are still abundant. The evidence we now have is quite as strongly in favor of a migration of Marsupials from America to the Old World, as the reverse, which has been supposed by some naturalists. Possibly, as Huxley has suggested, both countries were peopled with these low mammals from a continent now submerged.

The Edentate mammals have long been a puzzle to zoölogists, and up to the present time no clew to their affinities with other groups seems to have been detected. A comparison of the peculiar Eocene mammals which I have called the *Tillodontia*, with the least specialized Edentates, brings to light many curious resemblances in the skull, teeth, skeleton, and feet. These suggest relationship, at least, and possibly we may yet find here the key to the Edentate genealogy. At present, the Tillodonts are all from the lower and middle Eocene, while *Moropus*, the oldest Edentate genus, is found in the middle Miocene, and one species in the lower Pliocene.

The Edentates have been usually regarded as an American type, but the few living forms in Africa, and the Tertiary species in Europe, the oldest known, have made the land of their nativity uncertain. I have already given you some reasons for believing that the Edentates had their first home in North America, and migrated thence to the southern portion of the continent. This movement could not have taken place in the Miocene period, as the Isthmus of Darien was then submerged; but, near the close of the Tertiary, the elevation of this region left a much broader strip of land than now exists there, and over this the Edentates and other mammals made their way, perhaps urged on by the increasing cold of the glacial winters. The evidence to-day is strongly in favor of such a southern migration. This, how-

ever, leaves the Old World Edentates, fossil and recent, unaccounted for; but I believe the solution of this problem is essentially the same, namely, a migration from North America. The Miocene representatives of this group, which I have recently obtained in Oregon, are older than any known in Europe, and, strangely enough, are more like the latter and the existing African types than like any of our living species. If, now, we bear in mind that an elevation of only 180 feet would close Behring's Straits, and give a road thirty miles wide from America to Asia, we can easily see how this migration might have taken place. That such a Tertiary bridge did exist, we have much independent testimony, and the known facts all point to extensive migrations of animals over it.

The *Cetacea* are connected with the marine Carnivores through the genus *Zeuglodon*, as Huxley has shown, and the points of resemblance are so marked that the affinity cannot be doubted. That the connection was a direct one, however, is hardly probable, since the diminutive brain, large number of simple teeth, and reduced limbs in the whales, all indicate them to be an old type, which doubtless branched off from the more primitive stock leading to the Carnivores. Our American extinct Cetaceans, when carefully investigated, promise to throw much light upon the pedigree of these strange mammals. As most of the known forms were probably marine, their distribution is of little service in determining their origin.

That the Sirenians are allied to the Ungulates is now generally admitted by anatomists, and the separation of the existing species in distant localities suggests that they are the remnants of an extensive group, once widely distributed. The large number of teeth in some forms, the reduced limbs, and other characters, point back to an ancestry near that of the earliest Ungulates. The gradual loss of teeth in the specialized members of this group, and in the Cetaceans, is quite parallel with the same change in Edentates, as well as in Pterodactyles and Birds.

The Ungulates are so distinct from other groups that they must be one of the oldest natural divisions of mammals, and they probably originated from some herbivorous marsupial. Their large size, and great numbers, during Tertiary and Post-Tertiary time, render them most valuable in tracing migrations induced by climate, as well as in showing the changes of structure which such a contest for existence may produce.

In the review of the extinct Ungulates, I have endeavored to show that quite a number of genera, usually supposed to belong originally to the Old World, are in reality true American types. Among these were the horse, rhinoceros, and tapir, all the existing odd-toed Ungulates, and, besides these, the camel, pig, and deer. All these I believe, and many others, went to Asia from our Northwest coast. It must, for the present, remain an open question whether we may not fairly

claim the *Bovidæ*, and even the *Proboscidea*, since both occur in our strata at about the same horizon as on the other continent. On this point there is some confusion, at least in names. The Himalayan deposits called upper Miocene, and so rich in Proboscidians, indicate in their entire fauna that they are more recent than our Niobrara River beds, which, for apparently good reasons, we regard as lower Pliocene. The latter appear to be about the same horizon as the Pikermi deposits in Greece, also regarded as Miocene. Believing, however, that we have here a more complete Tertiary series, and a better standard for comparison of faunas, I have preferred to retain the names already applied to our divisions, until the strata of the two continents are more satisfactorily coördinated.

The extinct Rodents, Bats, and Insectivores of America, although offering many suggestive hints as to their relationship with other groups, and their various migrations, cannot now be fully discussed. There is little doubt, however, that the Rodents are a New World type, and, according to present evidence, they probably had their origin in North America. The resemblance in so many respects of this order to the Proboscidians is a striking fact, not yet explained by the imperfectly known genealogy of either group.

The Carnivores, too, I must pass by, except to call attention to a few special forms which accompanied the migrations of other groups. One of these is *Machairodus*, the sabre-toothed tiger, which flourished in our Miocene and Pliocene, and apparently followed the huge Edentates to South America, and the Ungulates across Asia to Europe. With this genus went *Hyænodon*, and some typical wolves and cats, but the bears probably came the other way with the antelopes. That the gazelle, giraffe, hippopotamus, hyena, and other African types, once abundant in Asia, did not come, is doubtless because the Miocene bridge was submerged before they reached it.

The Edentates, in their southern migration, were probably accompanied by the horse, tapir, and rhinoceros, although no remains of the last have yet been found south of Mexico. The mastodon, elephant, llama, deer, peccary, and other mammals, followed the same path. Why the mastodon, elephant, rhinoceros, and especially the horse, should have been selected with the huge Edentates for extinction, and the other Ungulates left, is at present a mystery, which their somewhat larger size hardly explains.

The relations of the American Primates, extinct and recent, to those of the other hemisphere, offer an inviting topic, but it is not within my present province to discuss them in their most suggestive phases. As we have here the oldest and most generalized members of the group, so far as now known, we may justly claim America for the birthplace of the order. That the development did not continue here until it culminated in man, was due to causes which at present we can only surmise, although the genealogy of other surviving groups gives

some data toward a solution. Why the Old World apes, when differentiated, did not come to the land of their earlier ancestry, is readily explained by the then intervening oceans, which likewise were a barrier to the return of the horse and rhinoceros.

Man, however, came—doubtless first across Behring's Straits; and at his advent became part of our fauna, as a mammal and primate. In these relations alone it is my purpose here to treat him. The evidence, as it stands to-day, although not conclusive, seems to place the first appearance of man in this country in the Pliocene, and the best proof of this has been found on the Pacific coast. During several visits to that region, many facts were brought to my knowledge which render this more than probable. Man at this time was a savage, and was doubtless forced by the great volcanic outbreaks to continue his migration. This was at first to the south, since mountain-chains were barriers on the east. As the native horses of America were now all extinct, and as the early man did not bring the Old World animal with him, his migrations were slow. I believe, moreover, that his slow progress toward civilization was in no small degree due to this same cause, the absence of the horse.

It is far from my intention to add to the many theories extant in regard to the early civilizations in this country, and their connections with the primitive inhabitants, or the later Indians; but two or three facts have recently come to my knowledge which I think worth mentioning in this connection. On the Columbia River, I have found evidence of the former existence of inhabitants much superior to the Indians at present there, and of which no tradition remains. Among many stone carvings which I saw there, were a number of heads which so strongly resemble those of apes that the likeness at once suggests itself. Whence came these sculptures, and by whom were they made? Another fact that has interested me very much is the strong resemblance between the skulls of the typical mound-builders of the Mississippi Valley and those of the Pueblo Indians. I had long been familiar with the former; and, when I recently saw the latter, it required the positive assurance of a friend, who had himself collected them in New Mexico, to convince me that they were not from the mounds. A third fact, and I leave man to the archæologists, on whose province I am even now trenching. In a large collection of mound-builders' pottery, over a thousand specimens, which I have recently examined with some care, I found many pieces of elaborate workmanship so nearly like the ancient water-jars from Peru, that no one could fairly doubt that some intercourse had taken place between the widely-separated people that made them.

The oldest known remains of man on this continent differ in no important characters from the bones of the typical Indian, although in some minor details they indicate a much more primitive race. These early remains, some of which are true fossils, resemble much more

closely the corresponding parts of the highest Old World apes, than do the latter our Tertiary Primates, or even the recent American monkeys. Various living and fossil forms of Old World Primates fill up essentially the latter gap. The lesser gap between the primitive man of America and the Anthropoid apes is partially closed by still lower forms of men, and doubtless also by higher apes, now extinct. Analogy, and many facts as well, indicate that this gap was smaller in the past. It certainly is becoming wider now with every generation, for the lowest races of men will soon become extinct, like the Tasmanians, and the highest apes cannot long survive. Hence the intermediate forms of the past, if any there were, become of still greater importance. For such missing links, we must look to the caves and later Tertiary of Africa, which I regard as now the most promising field for exploration in the Old World. America, even in the tropics, can promise no such inducements to ambitious explorers. We have, however, an equally important field, if less attractive, in the Cretaceous mammals, which must have left their remains somewhere on this continent. In these two directions, as I believe, lie the most important future discoveries in paleontology.

As a cause for many changes of structure in mammals during the Tertiary and Post-Tertiary, I regard as the most potent, *natural selection*, in the broad sense in which that term is now used by American evolutionists. Under this head I include not merely a Malthusian struggle for life among the animals themselves, but the equally important contest with the elements and all surrounding Nature. By changes in the environment, migrations are enforced, slowly in some cases, rapidly in others, and with change of locality must come adaptation to new conditions, or extinction. The life-history of Tertiary mammals illustrates this principle at every stage, and no other explanation meets the facts.

The real progress of mammalian life in America, from the beginning of the Tertiary to the present, is well illustrated by the brain-growth, in which we have the key to many other changes. The earliest known Tertiary mammals all had very small brains, and in some forms this organ was proportionally less than in certain reptiles. There was a gradual increase in the size of the brain during this period, and it is interesting to find that this growth was mainly confined to the cerebral hemispheres, or higher portion of the brain. In most groups of mammals, the brain has gradually become more convoluted, and thus increased in quality as well as quantity. In some, also, the cerebellum and olfactory lobes, the lower parts of the brain, have even diminished in size. In the long struggle for existence during Tertiary time, the big brains won, then as now; and the increasing power thus gained rendered useless many structures inherited from primitive ancestors, but no longer adapted to new conditions.

Another of the interesting changes in mammals during Tertiary time was in the teeth, which were gradually modified with other parts of the structure. The primitive form of tooth was clearly a cone, and all others are derived from this. All classes of Vertebrates below mammals, namely, fishes, amphibians, reptiles, and birds, have conical teeth, if any, or some simple modification of this form. The Edentates and Cetaceans with teeth retain this type, except the zeuglodonts, which approach the dentition of aquatic Carnivores. In the higher mammals, the incisors and canines retain the conical shape, and the premolars have only in part been transformed. The latter gradually change to the more complicated molar pattern, and hence are not reduced molars, but transition forms from the cone to more complex types. Most of the early Tertiary mammals had forty-four teeth, and in the oldest forms the premolars were all unlike the molars, while the crowns were short, covered with enamel, and without cement. Each stage of progress in the differentiation of the animal was, as a rule, marked by a change in the teeth; one of the most common being the transfer, in form at least, of a premolar to the molar series, and a gradual lengthening of the crown. Hence, it is often easy to decide from a fragment of a jaw to what horizon of the Tertiary it belongs. The fossil horses of this period, for example, gained a grinding-tooth for each toe they lost, one in each epoch. In the single-toed existing horses, all the premolars are like the molars, and the process is at an end. Other dental transformations are of equal interest, but this illustration must suffice.

The changes in the limbs and feet of mammals during the same period were quite as marked. The foot of the primitive mammal was, doubtless, plantigrade, and certainly five-toed. Many of the early Tertiary forms show this feature, which is still seen in some existing forms. This generalized foot became modified by a gradual loss of the outer toes, and increase in size of the central ones, the reduction proceeding according to systematic methods, differing in each group. Corresponding changes took place in the limb-bones. One result was a great increase in speed, as the power was applied so as to act only in the plane of motion. The best effect of this specialization is seen to-day in the horse and antelope, each representing a distinct group of Ungulates, with five-toed ancestors.

If the history of American mammals, as I have briefly sketched it, seems, as a whole, incomplete and unsatisfactory, we must remember that the genealogical tree of this class has its trunk and larger limbs concealed beneath the *débris* of Mesozoic time, while its roots doubtless strike so deeply into the Paleozoic that for the present they are lost. A decade or two hence we shall probably know something of the mammalian fauna of the Cretaceous, and the earlier lineage of our existing mammals can then be traced with more certainty.

The results I have presented to you are mainly derived from personal observation; and, since a large part of the higher vertebrate remains hitherto found in this country have passed through my hands, I am willing to assume full responsibility for my presentation of the subject.

For our present knowledge of the extinct Mammals, Birds, and Reptiles of North America, science is especially indebted to Leidy, whose careful, conscientious work has laid a secure foundation for our vertebrate paleontology. The energy of Cope has brought to notice many strange forms, and greatly enlarged our literature. Agassiz, Owen, Wyman, Baird, Hitchcock, Deane, Emmons, Lea, Allen, Gibbes, Jefferson, DeKay, and Harlan, deserve honorable mention in the history of this branch of science. The South American extinct Vertebrates have been described by Lund, Owen, Burmeister, Gervais, Huxley, Flower, Desmarest, Aymard, Pictet, and Nodot. Darwin and Wallace have likewise contributed valuable information on this subject, as they have on nearly all forms of life.

In this long history of ancient life I have said nothing of what Life itself really is—and for the best of reasons—because I know nothing. Here, at present, our ignorance is dense, and yet we need not despair. Light, Heat, Electricity, and Magnetism, Chemical Affinity, and Motion, are now considered different forms of the same force; and the opinion is rapidly gaining ground that Life, or vital force, is only another phase of the same power. Possibly the great mystery of Life may thus be solved, but, whether it be or not, a true faith in science knows no limit to its search for Truth.

THE WICKED WEASEL.

THERE are other enemies of game-life besides human poachers whose numbers must be kept within bounds to insure successful sport. The thirst of the weasel for blood is insatiable, and it is curious to watch the persistency with which he will hunt down the particular rabbit he has singled out for destruction. Through the winding subterranean galleries of the "buries" with their cross-passages, "blind" holes and "pop" holes (i. e., those which end in undisturbed soil, and those which are simply bored from one side of the bank to the other, being only used for temporary concealment), never once in the dark, close caverns losing sight or scent of his victim, he pursues it with a species of eager patience. It is generally a long chase. The rabbit makes a dash ahead, and a double or two, and then halts, usually at the mouth of a hole; perhaps to breathe.

By-and-by the weasel, baffled for a few minutes, comes up behind. Instantly the rabbit slips over the bank outside and down the ditch for a dozen yards, and there enters the "bury" again. The weasel follows, gliding up the bank with a motion not unlike that of the snake; for his body and neck are long and slender, and his legs short. Apparently he is not in haste, but rather lingers over the scent. This is repeated five or six times, till the whole length of the hedgerow has been traversed—sometimes up and down again. The chase may be easily observed by any one who will keep a little in the background. Although the bank be tenanted by fifty other rabbits, past whose hiding-place the weasel must go, yet they scarcely take any notice. One or two, whom he has approached too closely, bolt out and in again; but as a mass the furry population remain quiet, as if perfectly aware that they are not yet marked out for slaughter. At last, having exhausted the resources of the bank, the rabbit rushes across the field to a hedgerow, perhaps a hundred yards away. Here the wretched creature seems to find a difficulty in obtaining admittance. Hardly has he disappeared in a hole before he comes out again, as if the inhabitants of the place refused to give him shelter. For many animals have a strong tribal feeling, and their sympathy, like that of man in a savage state, is confined within their special settlement. With birds it is the same; rooks, for instance, will not allow a strange pair to build in their trees, but drive them off with relentless beak, tearing down the half-formed nest, and taking the materials to their own use. The sentiment, "If Jacob take a wife of the daughters of Heth, what good shall my life do me?" appears to animate the breasts of gregarious creatures of this kind. Rooks intermarry generation after generation; and if a black lover brings home a foreign bride, they are forced to build in a tree at some distance. Near large rookeries several such outlying colonies may be seen.

The rabbit, failing to find a cover, hides in the grass and dry rushes; but across the meadow, stealing along the furrow, comes the weasel; and, shift his place how he may, in the end, worn out and weary, bunny succumbs, and the sharp teeth meet in the neck behind the ear, severing the vein. Ofter in the end the rabbit runs to earth in a hole which is a *cul-de-sac*, with his back toward the pursuer. The weasel, unable to get at the poll, which is his desire, will mangle the hinder parts in a terrible manner—as will the civilized ferret under similar conditions. Now and then the rabbit, scratching and struggling, fills the hole in the rear with earth, and so at the last moment chokes off his assailant and finds safety almost in the death-agony. In the woods, once the rabbit is away from the "buries," the chase really does resemble a hunt; from furze-bush to bracken, from fern to rough grass, round and round, backward, doubling, to and fro, and all in vain. At such times, eager for blood, the weasel

will run right across your path, almost close enough to be kicked. Pursue him in turn, and if there be no hedge or hole near, if you have him in the open, he will dart hither and thither right between your legs, uttering a sharp, short note of anger and alarm, something composed of a tiny bark and a scream. He is easily killed with a stick when you catch him in the open, for he is by no means swift; but if a hedge be near it is impossible to secure him.

Weasels frequently hunt in couples, and sometimes more than two will work together. We once saw five, and have heard of eight. The five we saw were working a sandy bank drilled with holes, from which the rabbits in wild alarm were darting in all directions. The weasels raced from hole to hole and along the sides of the bank exactly like a pack of hounds, and seemed intensely excited. Their manner of hunting resembles the motions of ants; these insects run a little way very swiftly, then stop, turn to the right or left, make a short *détour*, and afterward on again in a straight line. So the pack of weasels darted forward, stopped, went from side to side, and then on a yard or two, and repeated the process. To see their reddish heads thrust for a moment from the holes, then withdrawn to reappear at another, would have been amusing had it not been for the reflection that their frisky tricks would assuredly end in death. They ran their quarry out of the bank and into a wood, where we lost sight of them. The pack of eight was seen by a laborer returning down a woodland lane from work one afternoon. He told us he got in the ditch, half from curiosity to watch them, and half from fear—laughable as that may seem—for he had heard the old people tell stories of men in the days when the corn was kept for years in barns, and so bred hundreds of rats, being attacked by those vicious brutes. He said they made a noise, crying to each other—short, sharp, snappy sounds; but the pack of five we ourselves saw hunted in silence.

Often and often, when standing in a gateway, partly hidden by the bushes, watching the woodpecker on the ant-hills, of whose eggs, too, the partridges are so fond (so that a good ant year, in which their nests are prolific, is also a good partridge year), you may, if you are still, hear a slight, faint rustle in the hedge, and by-and-by a weasel will steal out. Seeing you he instantly pauses, elevates his head, and steadily gazes; move but your eyes, and he is back in the hedge; remain quiet, still looking straight before you as if you saw nothing, and he will presently recover confidence, and actually cross the gateway almost under you. This is the secret of observation: stillness, silence, and apparent indifference. In some instinctive way these wild creatures learn to distinguish when one is or is not intent upon them in a spirit of enmity; and, if very near, it is always the eye they watch. So long as you observe them, as it were, from the corner of the eyeball, sidewise, or look over their heads at something beyond, it is well. Turn your glance full upon them to get a better

view, and they are gone. When waiting in a dry ditch with a gun on a warm autumn afternoon for a rabbit to come out, sometimes a bunny will suddenly appear at the mouth of a hole which your knee nearly touches. He stops dead, as if petrified with astonishment, sitting on his haunches. His full dark eye is on you with a gaze of intense curiosity; his nostrils work as if sniffing; his whiskers move; and every now and then he thumps with his hind-legs upon the earth with a low, dull thud. This is evidently a sign of great alarm, at the noise of which any other rabbit within hearing instantly disappears in the "bury." Yet there your friend sits and watches you as if spellbound, so long as you have the patience to move neither hand nor foot nor to turn your eye. Keep your glance on the frond of the fern just beyond him, and he will stay. The instant your eye meets his, or a finger stirs, he plunges out of sight. It is so also with birds. Walk across a meadow, swinging a stick, even humming, and the rooks calmly continue their search for grubs within thirty yards; stop to look at them, and they rise on the wing directly. So, too, the finches in the trees by the road-side. Let the wayfarer pass beneath the bough on which they are singing, and they will sing on, if he moves without apparent interest; should he pause to listen, their wings glisten in the sun as they fly.

Stoats, though not so numerous as weasels, probably do quite as much injury, being larger, swifter, stronger, and very bold, sometimes entering sheds close to dwelling-houses. The laboring-people—at least, the elder folk—declare that they have been known to suck the blood of infants left asleep in the cradle upon the floor, biting the child behind the ear. They hunt in couples also—seldom in larger numbers. We have seen three at work together, and with a single shot killed two out of the trio. In elegance of shape they surpass the weasel, and the color is brighter. Their range of destruction seems only limited by their strength; they attack anything they can manage.

The keeper looks upon weasel and stoat as bitter foes, to be ruthlessly exterminated with shot and gin. He lays to their charge deadly crimes of murder, the death of rabbits, hares, birds, the theft and destruction of his young broods, even occasional abstraction of a chicken close to his very door, despite the dogs chained there. They are not easily shot, being quick to take shelter at the sight of a dog, and, when hard hit with the pellets, frequently escaping, though perhaps to die. Both weasel and stoat, and especially the latter, will snap viciously at the dog that overtakes them, even when sore wounded, always aiming to fix their teeth in his nose, and fighting savagely to the last gasp. The keeper slays a wonderful number in the course of a year, yet they seem as plentiful as ever. He traps perhaps more than he shoots. It is not always safe to touch a stoat caught in a trap; he lies apparently dead, but lift him up, and instantly his teeth are in your hand, and it is said such wounds some-

times fester for months. Stoats are tough as leather; though severely nipped by the iron fangs of the gin, struck on the head with the butt of the gun, and seemingly quite lifeless, yet, if thrown on the grass and left, you will often find on returning to the place in a few hours time that the animal is gone. Warned by experiences of this kind, the keeper never picks up a stoat till "settled" with a stick or shot, and never leaves him till he is nailed to the shed. Stoats sometimes emit a disgusting odor when caught in a trap. The keeper has no mercy for such vermin, though he thinks some other of his enemies are even more destructive.—*Pall Mall Budget.*

THE DISSIPATION OF ENERGY.

By GEORGE ILES.

SCARCELY had the grand truth been well demonstrated, some thirty years ago, that force can neither be created nor annihilated, when it served as a basis for one of the boldest theories ever conceived in the history of science. Prof. William Thomson (now Prof. Sir William Thomson) in 1853 first broached the theory of the dissipation of energy, and since that time many other eminent men have enlarged it and speculated upon it.

The theory points out, in the first place, that different phases of energy are not transformable into one another with equal ease and completeness. Heat is the only form into which any other can be totally converted. When electricity, mechanical motion, or any kind of energy but heat is sought, an undesired production of thermal effect is unavoidable in the most favorable conditions for efficient conversion known to science. Therefore, in the catalogue of terrestrial forces heat is continually gaining in amount at the expense of every other mode of motion.

Further, not only is it impossible, by any known method, to regain from heat more than one-fourth its theoretical value in useful work, but, as the tendency of all heat is ever to become of uniform temperature, by radiation and conduction, the differences of degree wherein its value as a source of other motion solely lies are being continually abolished. The tendency of energy to appear more and more as uniformly diffused heat is further shown to be true not only on earth but in the heavens. With respect to the solar system, our present information, it is held, indicates that it is gradually drifting toward an utterly lifeless state. The sun is parting with its stores of force most lavishly, and must, at however distant a period, become as cold as its planets are now. The planets are little by little losing their force of axial rotation from the friction of their tides, which transmute it into heat;

at some future age they will doubtless present a single side to the sun, as our moon, from similar causes, now does to the earth.

Furthermore, it is thought that the medium which conveys light through space, extremely attenuated though it may be, is capable of opposing some resistance to planetary movements, so that the sun may at last unite with itself all the orbs now circling around it. The collision between the sun and its worlds would render the whole mass fiery hot; but radiation, in the course of time, would slowly bring its temperature lower and lower, until it would cease to shine altogether. The theory then supposes that the fate which shall have overtaken the solar system will then attack the sidereal heavens; that the causes which shall first make the planets unite with their primary will make stars unite with one another, until the ultimate result of all these changes may be that a solitary gigantic ball shall contain all the matter now interfused through space, its enormous store of energy, in the form of equably-diffused heat, being incapable of further change, and utterly unfit for the production or maintenance of life.

All this is assuredly very bold, and deduced most fairly from its premises; but premises in truth and completeness are of much more account and far more difficult of discovery than methods of logical inference. Let us briefly examine the grounds on which it is supposed that Nature is doomed to a death without resurrection, and see if they warrant the tremendous conclusions drawn from them.

The theory illustrates very pointedly the difficulties in which the finite mind of man becomes involved when it attempts to deal with what is not thinkably finite—or, if the term be preferred, infinite. In the first place, the theory under consideration assumes the finiteness in amount of matter and motion; but we do not know, nor can we imagine, that space has bounds, neither can we limit the extent of the orbs and movements which, as far as we can see, occupy it.

Secondly, the theory makes another conjecture in the realm of the absolute, when it presumes that heat is an absolutely homogeneous motion—that particles endowed with it move with so perfect a uniformity that there is an exclusion of any difference of motion which might serve as a starting-point for mechanical changes. But has science advanced far enough to make such a proposition tenable? Our knowledge of the ultimate structure of matter is very restricted; and as to what the modes of motion are which we call heat, electricity, and so on, we are entirely in the dark. Their quantities we know, but their qualities, their peculiar orbits, have scarcely been guessed at as yet. From a variety of reasons, however, the modern opinion, like the ancient one, is that matter is made up of atoms, which in the circumstances are units even if ideally divisible. Approximate measurements of them have been made by Prof. Sir William Thomson himself. (*See* his paper in *Nature*, vol. i., p. 551.)

Now, if atoms by virtue of their heat moved uninterruptedly in a

simple straight line, their motion would be uniform and undifferenced; but, as neither the position nor the size of a mass undergoes change when temperature does not vary, atomic paths must suffer oft-repeated stops. Elastic particles in this state must have incessantly fluctuating velocities, yet always oscillating about a fixed mean. Matter endued with heat cannot have its particles in absolute contact, or the compressibility or contractibility which is the inseparable property of any mass would not exist. For argument's sake, however, let it be admitted that from absolute contact or any other cause heat-motion is a uniform one. If it be a purely axial rotation, then the equators of the atoms move faster than the poles, and the movement is not homogeneous. Exactly so, if the atom describe as an orbit a circle, ellipse, or other figure recurrently. Such motion would involve axial rotation, the atom would resemble our earth, and different parts of it would move with different velocities. In the case of two tangible spheres of like dimensions it is easy to show that, when swiftly moving at an equal rate, the speed of the one can be accelerated at the expense of the other, by applying it at a point not equatorial to the equator of its neighbor. In some such way it is conceivable that differences in molecular motion may widen from those subsisting between the parts of an individual molecule.

The imperfect homogeneity of thermal motion, which is here contended for, has some palpable parallels in the distribution of two other phases of energy—electricity of high tension and magnetism; these forces are cumulative in their manifestations, increasing in intensity toward the poles of the masses presenting them.

Thirdly, it is not strictly an accurate premise in the theory that, when heat is produced from any other force, it is unaccompanied by any phase of energy not thermal. Increments of heat invariably alter the dimensions of bodies, as a rule expand them, and thus part of the original energy applied appears as gravity. The sun in warming the earth's atmosphere lifts it, and, when the air cools, its fall is of no insignificant dynamic value. What is so evident in this extreme case is true of any mass whatever when heated. Not only is heat pitted against gravity, but at times against cohesive and crystalline forces, which, though overcome, must modify and diminish its effects.

There is a check to the continuous increase of temperature which is of much more importance than those just noted, but akin to them. A compound substance receives additions of heat with tolerable evenness up to a certain point, when it is resolved into two or more simple constituents, according to its complexity. These if compound are in turn decomposed into their chemical elements if more heat be applied. Now, chemical energy is a motion quite distinct by itself, and we find that heat in its higher degrees must coexist with it. So that on this account we cannot accept the notion that heat is ever to become the only kind of motion in the universe. In so doing we recog-

nize another reason for believing that Nature will never attain absolute equilibrium, from the variety of forces ever abiding together within her sphere.

Fourthly, our present inability to obtain the movement of masses from the motion of molecules or small masses—that is, the derivation of work from uniformly heated matter—does not decide that such conversion is impossible in Nature, or even to science in the future. While it is perfectly right to reason from what we know, it is of yet higher importance to constantly bear in mind how little we know. It would require infinite knowledge to say that the motion of uniform heat may not be transformable into phases of energy quite as diverse as high and low temperatures.

Such a change would not contravene the truth of the uncreatability or indestructibility of force, but would simply be an enlargement of the known, which every one feels to be indefinitely small as compared with the knowable. The possibility here suggested may be conceivable as depending on the definiteness in size of atoms; or, on the variety of motions to which the differences between atoms, as chemical elements, may give rise—differences in size and form; or, on the variety of motions implied by the checks offered to steady accessions of temperature, already explained in this paper.

One of the first principles to which the mind clings as fundamental is, that every truth has its converse. Although this may seem an axiom, yet its demonstration may be often very difficult, and, at times, even impossible. A knife-blade held over a gas-flame for a moment shows that hydrogen and oxygen combine to form watery vapor; yet the proof of the converse—the decomposition of water into its elements—demands extensive and powerful apparatus. Oersted, in a happy hour, noticed that an electric wire moved a magnetic needle; but years of experiment had to elapse before the electro-magnet and the magneto-electric machine established the complementary principles in a practical form. The analysis of compounds, chemically, is vastly easier than the building them up from their elements. We know the exact percentages of carbon, hydrogen, and oxygen, that go to make up sugar, and can express to a nicety the dynamical relations of the compound to its elements; but *how* to bring about the changes desired, with economy, is what puzzles us.

When we see high and low temperatures coming to an equality, it is certainly permissible to entertain faith in the possibility of the converse; in a change equivalent to a mass becoming, in its several parts, hotter and colder. To have recourse to such a supposition is less straining to the mind than the alternatives usually proposed by the theory under consideration.

If that theory be true, the question suggests itself, "Why has not the universe come to death by this time, for limits cannot be imagined to past duration?"

To this two replies have been given by the maintainers of the theory: That the universe has either had a beginning in time; or that, if it be really eternal, there are revolutions in its laws unknowable to man—interpositions of Creative Will!

These men of science are plainly not afraid of carrying out their opinions rigorously to their logical conclusions, but is their information as to the nature and relations of the phases of energy wide and deep enough to warrant them in framing an hypothesis so lofty as to include the cosmos and eternity? Hardly.

At the present stage of science, a student pondering the subject so briefly presented here may be compared to a judge before whom a few witnesses in an important case have appeared. As he hears each one, he makes, for convenience' sake, a provisional summing-up, and tacks the testimony together in one directive line. But it would be a most injudicial act to mistake a provisional opinion for a final judgment, and, with an indefinite number of witnesses unheard, to pronounce sentence of death.

ILLUSTRATIONS OF THE LOGIC OF SCIENCE.

By C. S. PEIRCE,

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FOURTH PAPER.—THE PROBABILITY OF INDUCTION.

I.

WE have found that every argument derives its force from the general truth of the class of inferences to which it belongs; and that probability is the proportion of arguments carrying truth with them among those of any *genus*. This is most conveniently expressed in the nomenclature of the mediæval logicians. They called the fact expressed by a premise an *antecedent*, and that which follows from it its *consequent;* while the leading principle, that every (or almost every) such antecedent is followed by such a consequent, they termed the *consequence*. Using this language, we may say that probability belongs exclusively to *consequences*, and the probability of any consequence is the number of times in which antecedent and consequent both occur divided by the number of all the times in which the antecedent occurs. From this definition are deduced the following rules for the addition and multiplication of probabilities:

Rule for the Addition of Probabilities.—Given the separate probabilities of two consequences having the same antecedent and incompatible consequents. Then the sum of these two numbers is the probability of the consequence, that from the same antecedent one or other of those consequents follows.

Rule for the Multiplication of Probabilities.—Given the separate probabilities of the two consequences, "If A then B," and "If both A and B, then C." Then the product of these two numbers is the probability of the consequence, "If A, then both B and C."

Special Rule for the Multiplication of Independent Probabilities.—Given the separate probabilities of two consequences having the same antecedents, "If A, then B," and "If A, then C." Suppose that these consequences are such that the probability of the second is equal to the probability of the consequence, "If both A and B, then C." Then the product of the two given numbers is equal to the probability of the consequence, "If A, then both B and C."

To show the working of these rules we may examine the probabilities in regard to throwing dice. What is the probability of throwing a six with one die? The antecedent here is the event of throwing a die; the consequent, its turning up a six. As the die has six sides, all of which are turned up with equal frequency, the probability of turning up any one is $\frac{1}{6}$. Suppose two dice are thrown, what is the probability of throwing sixes? The probability of either coming up six is obviously the same when both are thrown as when one is thrown —namely, $\frac{1}{6}$. The probability that either will come up six when the other does is also the same as that of its coming up six whether the other does or not. The probabilities are, therefore, independent; and, by our rule, the probability that both events will happen together is the product of their several probabilities, or $\frac{1}{6} \times \frac{1}{6}$. What is the probability of throwing deuce-ace? The probability that the first die will turn up ace and the second deuce is the same as the probability that both will turn up sixes—namely, $\frac{1}{36}$; the probability that the *second* will turn up ace and the *first* deuce is likewise $\frac{1}{36}$; these two events—first, ace; second, deuce; and, second, ace; first, deuce —are incompatible. Hence the rule for addition holds, and the probability that either will come up ace and the other deuce is $\frac{1}{36} + \frac{1}{36}$, or $\frac{1}{18}$.

In this way all problems about dice, etc., may be solved. When the number of dice thrown is supposed very large, mathematics (which may be defined as the art of making groups to facilitate numeration) comes to our aid with certain devices to reduce the difficulties.

II.

The conception of probability as a matter of *fact*, i. e., as the proportion of times in which an occurrence of one kind is accompanied by an occurrence of another kind, is termed by Mr. Venn the materialistic view of the subject. But probability has often been regarded as being simply the degree of belief which ought to attach to a proposition; and this mode of explaining the idea is termed by Venn the conceptualistic view. Most writers have mixed the two conceptions together. They, first, define the probability of an event as the reason

we have to believe that it has taken place, which is conceptualistic; but shortly after they state that it is the ratio of the number of cases favorable to the event to the total number of cases favorable or contrary, and all equally possible. Except that this introduces the thoroughly unclear idea of cases equally possible in place of cases equally frequent, this is a tolerable statement of the materialistic view. The pure conceptualistic theory has been best expounded by Mr. De Morgan in his "Formal Logic: or, the Calculus of Inference, Necessary and Probable."

The great difference between the two analyses is, that the conceptualists refer probability to an event, while the materialists make it the ratio of frequency of events of a *species* to those of a *genus* over that *species*, thus *giving it two terms instead of one.* The opposition may be made to appear as follows:

Suppose that we have two rules of inference, such that, of all the questions to the solution of which both can be applied, the first yields correct answers to $\frac{81}{100}$, and incorrect answers to the remaining $\frac{19}{100}$; while the second yields correct answers to $\frac{93}{100}$, and incorrect answers to the remaining $\frac{7}{100}$. Suppose, further, that the two rules are entirely independent as to their truth, so that the second answers correctly $\frac{93}{100}$ of the questions which the first answers correctly, and also $\frac{93}{100}$ of the questions which the first answers incorrectly, and answers incorrectly the remaining $\frac{7}{100}$ of the questions which the first answers correctly, and also the remaining $\frac{7}{100}$ of the questions which the first answers incorrectly. Then, of all the questions to the solution of which both rules can be applied—

both answer correctly..... $\frac{93}{100}$ of $\frac{81}{100}$, or $\frac{93 \times 81}{100 \times 100}$;

the second answers correctly and the first incorrectly..... $\frac{93}{100}$ of $\frac{19}{100}$, or $\frac{93 \times 19}{100 \times 100}$;

the second answers incorrectly and the first correctly..... $\frac{7}{100}$ of $\frac{81}{100}$, or $\frac{7 \times 81}{100 \times 100}$;

and both answer correctly..... $\frac{7}{100}$ of $\frac{19}{100}$, or $\frac{7 \times 19}{100 \times 100}$;

Suppose, now, that, in reference to any question, both give the same answer. Then (the questions being always such as are to be answered by *yes* or *no*), those in reference to which their answers agree are the same as those which both answer correctly together with those which both answer falsely, or $\frac{93 \times 81}{100 \times 100} + \frac{7 \times 19}{100 \times 100}$ of all. The proportion of those which both answer correctly out of those their answers to which agree is, therefore—

$$\frac{\frac{93 \times 81}{100 \times 100}}{\frac{93 \times 81}{100 \times 100} + \frac{7 \times 19}{100 \times 100}} \text{ or } \frac{93 \times 81}{(93 \times 81) + (7 \times 19)}.$$

This is, therefore, the probability that, if both modes of inference yield the same result, that result is correct. We may here conveniently make use of another mode of expression. *Probability* is the ratio of the favorable cases to all the cases. Instead of expressing our result in terms of this ratio, we may make use of another—the ratio of favorable to unfavorable cases. This last ratio may be called the *chance* of an event. Then the chance of a true answer by the first mode of inference is $\frac{81}{19}$ and by the second is $\frac{93}{7}$; and the chance of a correct answer from both, when they agree, is—

$$\frac{81 \times 93}{19 \times 7} \text{ or } \frac{81}{19} \times \frac{93}{7},$$

or the product of the chances of each singly yielding a true answer.

It will be seen that a chance is a quantity which may have any magnitude, however great. An event in whose favor there is an even chance, or $\frac{1}{1}$ has a probability of $\frac{1}{2}$. An argument having an even chance can do nothing toward reënforcing others, since according to the rule its combination with another would only multiply the chance of the latter by 1.

Probability and chance undoubtedly belong primarily to consequences, and are relative to premises; but we may, nevertheless, speak of the chance of an event absolutely, meaning by that the chance of the combination of all arguments in reference to it which exist for us in the given state of our knowledge. Taken in this sense it is incontestable that the chance of an event has an intimate connection with the degree of our belief in it. Belief is certainly something more than a mere feeling; yet there is a feeling of believing, and this feeling does and ought to vary with the chance of the thing believed, as deduced from all the arguments. Any quantity which varies with the chance might, therefore, it would seem, serve as a thermometer for the proper intensity of belief. Among all such quantities there is one which is peculiarly appropriate. When there is a very great chance, the feeling of belief ought to be very intense. Absolute certainty, or an infinite chance, can never be attained by mortals, and this may be represented appropriately by an infinite belief. As the chance diminishes the feeling of believing should diminish, until an even chance is reached, where it should completely vanish and not incline either toward or away from the proposition. When the chance becomes less, then a contrary belief should spring up and should increase in intensity as the chance diminishes, and as the chance almost vanishes (which it can never quite do) the contrary belief should tend toward an infinite intensity. Now, there is one quantity which, more simply than any other, fulfills these conditions; it is the *logarithm* of the chance. But there is another consideration which must, if admitted, fix us to this choice for our thermometer. It is that our belief ought to be proportional to the weight of evi-

dence, in this sense, that two arguments which are entirely independent, neither weakening nor strengthening each other, ought, when they concur, to produce a belief equal to the sum of the intensities of belief which either would produce separately. Now, we have seen that the chances of independent concurrent arguments are to be multiplied together to get the chance of their combination, and therefore the quantities which best express the intensities of belief should be such that they are to be *added* when the *chances* are multiplied in order to produce the quantity which corresponds to the combined chance. Now, the logarithm is the only quantity which fulfills this condition. There is a general law of sensibility, called Fechner's psychophysical law. It is that the intensity of any sensation is proportional to the logarithm of the external force which produces it. It is entirely in harmony with this law that the feeling of belief should be as the logarithm of the chance, this latter being the expression of the state of facts which produces the belief.

The rule for the combination of independent concurrent arguments takes a very simple form when expressed in terms of the intensity of belief, measured in the proposed way. It is this: Take the sum of all the feelings of belief which would be produced separately by all the arguments *pro*, subtract from that the similar sum for arguments *con*, and the remainder is the feeling of belief which we ought to have on the whole. This is a proceeding which men often resort to, under the name of *balancing reasons*.

These considerations constitute an argument in favor of the conceptualistic view. The kernel of it is that the conjoint probability of all the arguments in our possession, with reference to any fact, must be intimately connected with the just degree of our belief in that fact; and this point is supplemented by various others showing the consistency of the theory with itself and with the rest of our knowledge.

But probability, to have any value at all, must express a fact. It is, therefore, a thing to be inferred upon evidence. Let us, then, consider for a moment the formation of a belief of probability. Suppose we have a large bag of beans from which one has been secretly taken at random and hidden under a thimble. We are now to form a probable judgment of the color of that bean, by drawing others singly from the bag and looking at them, each one to be thrown back, and the whole well mixed up after each drawing. Suppose the first drawing is white and the next black. We conclude that there is not an immense preponderance of either color, and that there is something like an even chance that the bean under the thimble is black. But this judgment may be altered by the next few drawings. When we have drawn ten times, if 4, 5, or 6, are white, we have more confidence that the chance is even. When we have drawn a thousand times, if about half have been white, we have great confidence in this result.

We now feel pretty sure that, if we were to make a large number of bets upon the color of single beans drawn from the bag, we could approximately insure ourselves in the long run by betting each time upon the white, a confidence which would be entirely wanting if, instead of sampling the bag by 1,000 drawings, we had done so by only two. Now, as the whole utility of probability is to insure us in the long run, and as that assurance depends, not merely on the value of the chance, but also on the accuracy of the evaluation, it follows that we ought not to have the same feeling of belief in reference to all events of which the chance is even. In short, to express the proper state of our belief, not *one* number but *two* are requisite, the first depending on the inferred probability, the second on the amount of knowledge on which that probability is based.[1] It is true that when our knowledge is very precise, when we have made many drawings from the bag, or, as in most of the examples in the books, when the total contents of the bag are absolutely known, the number which expresses the uncertainty of the assumed probability and its liability to be changed by further experience may become insignificant, or utterly vanish. But, when our knowledge is very slight, this number may be even more important than the probability itself; and when we have no knowledge at all this completely overwhelms the other, so that there is no sense in saying that the chance of the totally unknown event is even (for what expresses absolutely no fact has absolutely no meaning), and what ought to be said is that the chance is entirely indefinite. We thus perceive that the conceptualistic view, though answering well enough in some cases, is quite inadequate.

Suppose that the first bean which we drew from our bag were black. That would constitute an argument, no matter how slender, that the bean under the thimble was also black. If the second bean were also to turn out black, that would be a second independent argument reënforcing the first. If the whole of the first twenty beans drawn should prove black, our confidence that the hidden bean was black would justly attain considerable strength. But suppose the twenty-first bean were to be white and that we were to go on drawing until we found that we had drawn 1,010 black beans and 990 white ones. We should conclude that our first twenty beans being black was simply an extraordinary accident, and that in fact the proportion of white beans to black was sensibly equal, and that it was an even chance that the hidden bean was black. Yet according to the rule of *balancing reasons*, since all the drawings of black beans are so many independent arguments in favor of the one under the thimble being black, and all the white drawings so many against it, an excess of twenty black beans ought to produce the same degree of belief that the hidden bean was black, whatever the total number drawn.

[1] Strictly we should need an infinite series of numbers each depending on the probable error of the last.

In the conceptualistic view of probability, complete ignorance, where the judgment ought not to swerve either toward or away from the hypothesis, is represented by the probability $\frac{1}{2}$.[1]

But let us suppose that we are totally ignorant what colored hair the inhabitants of Saturn have. Let us, then, take a color-chart in which all possible colors are shown shading into one another by imperceptible degrees. In such a chart the relative areas occupied by different classes of colors are perfectly arbitrary. Let us inclose such an area with a closed line, and ask what is the chance on conceptualistic principles that the color of the hair of the inhabitants of Saturn falls within that area? The answer cannot be indeterminate because we must be in some state of belief; and, indeed, conceptualistic writers do not admit indeterminate probabilities. As there is no certainty in the matter, the answer lies between *zero* and *unity*. As no numerical value is afforded by the data, the number must be determined by the nature of the scale of probability itself, and not by calculation from the data. The answer can, therefore, only be one-half, since the judgment should neither favor nor oppose the hypothesis. What is true of this area is true of any other one; and it will equally be true of a third area which embraces the other two. But the probability for each of the smaller areas being one-half, that for the larger should be at least unity, which is absurd.

III.

All our reasonings are of two kinds: 1. *Explicative, analytic*, or *deductive;* 2. *Amplifiative, synthetic*, or (loosely speaking) *inductive*. In explicative reasoning, certain facts are first laid down in the premises. These facts are, in every case, an inexhaustible multitude, but they may often be summed up in one simple proposition by means of some regularity which runs through them all. Thus, take the proposition that Socrates was a man; this implies (to go no further) that during every fraction of a second of his whole life (or, if you please, during the greater part of them) he was a man. He did not at one instant appear as a tree and at another as a dog; he did not flow into water, or appear in two places at once; you could not put your finger through him as if he were an optical image, etc. Now, the facts being thus laid down, some order among some of them, not particularly made use of for the purpose of stating them, may perhaps be discovered; and this will enable us to throw part or all of them into a new statement, the possibility of which might have escaped attention. Such a statement will be the conclusion of an analytic inference. Of this sort are all mathematical demonstrations. But synthetic reasoning is of another kind. In this case the facts summed up in the conclusion are not among those stated in the prem-

[1] "Perfect indecision, belief inclining neither way, an even chance."—De Morgan, p. 182.

ises. They are different facts, as when one sees that the tide rises m times and concludes that it will rise the next time. These are the only inferences which increase our real knowledge, however useful the others may be.

In any problem in probabilities, we have given the relative frequency of certain events, and we perceive that in these facts the relative frequency of another event is given in a hidden way. This being stated makes the solution. This is therefore mere explicative reasoning, and is evidently entirely inadequate to the representation of synthetic reasoning, which goes out beyond the facts given in the premises. There is, therefore, a manifest impossibility in so tracing out any probability for a synthetic conclusion.

Most treatises on probability contain a very different doctrine. They state, for example, that if one of the ancient denizens of the shores of the Mediterranean, who had never heard of tides, had gone to the bay of Biscay, and had there seen the tide rise, say m times, he could know that there was a probability equal to

$$\frac{m+1}{m+2}$$

that it would rise the next time. In a well-known work by Quetelet, much stress is laid on this, and it is made the foundation of a theory of inductive reasoning.

But this solution betrays its origin if we apply it to the case in which the man has never seen the tide rise at all; that is, if we put $m = 0$. In this case, the probability that it will rise the next time comes out $\frac{1}{2}$, or, in other words, the solution involves the conceptualistic principle that there is an even chance of a totally unknown event. The manner in which it has been reached has been by considering a number of urns all containing the same number of balls, part white and part black. One urn contains all white balls, another one black and the rest white, a third two black and the rest white, and so on, one urn for each proportion, until an urn is reached containing only black balls. But the only possible reason for drawing any analogy between such an arrangement and that of Nature is the principle that alternatives of which we know nothing must be considered as equally probable. But this principle, is absurd. There is an indefinite variety of ways of enumerating the different possibilities, which, on the application of this principle, would give different results. If there be any way of enumerating the possibilities so as to make them all equal, it is not that from which this solution is derived, but is the following: Suppose we had an immense granary filled with black and white balls well mixed up; and suppose each urn were filled by taking a fixed number of balls from this granary quite at random. The relative number of white balls in the granary might be anything, say one in three. Then in one-third of the urns the first ball would

be white, and in two-thirds black. In one-third of those urns of which the first ball was white, and also in one-third of those in which the first ball was black, the second ball would be white. In this way, we should have a distribution like that shown in the following table, where *w* stands for a white ball and *b* for a black one. The reader can, if he chooses, verify the table for himself.

wwww.

wwwb.	wwbw.	wbww.	bwww.		
wwwb.	wwbw.	wbww.	bwww.		
wwbb.	wbwb.	bwwb.	wbbw.	bwbw.	bbww.
wwbb.	wbwb.	bwwb.	wbbw.	bwbw.	bbww.
wwbb,	wbwb.	bwwb.	wbbw.	bwbw.	bbww.
wwbb.	wbwb.	bwwb.	wbbw.	bwbw.	bbww.
wbbb.	bwbb.	bbwb.	bbbw.		
wbbb.	bwbb.	bbwb.	bbbw.		
wbbb.	bwbb.	bbwb.	bbbw.		
wbbb.	bwbb.	bbwb.	bbbw.		
wbbb.	bwbb.	bbwb.	bbbw.		
wbbb.	bwbb.	bbwb.	bbbw.		
wbbb.	bwbb.	bbwb.	bbbw.		
wbbb.	bwbb.	bbwb.	bbbw.		

bbbb. In the second group, where there is one b, there are two
bbbb. sets just alike; in the third there are 4, in the fourth 8, and in
bbbb. the fifth 16, doubling every time. This is because we have
bbbb. supposed twice as many black balls in the granary as white
bbbb. ones; had we supposed 10 times as many, instead of
bbbb.

bbbb. 1, 2, 4, 8, 16

bbbb.
bbbb. sets we should have had
bbbb.

bbbb. 1, 10, 100, 1000, 10000

bbbb.
bbbb. sets; on the other hand, had the numbers of black and white
bbbb. balls in the granary been even, there would have been but
bbbb. one set in each group. Now suppose two balls were drawn
bbbb. from one of these urns and were found to be both white, what would be the probability of the next one being white? If the two drawn out were the first two put into the urns, and the next to be drawn out were the third put in, then the probability of this third being white would be the same whatever the colors of the first two, for it has been supposed that just the same proportion of urns has the third ball white among those which have the first two *white-white*, *white-black*, *black-white*, and *black-black*. Thus, in this case, the chance

of the third ball being white would be the same whatever the first two were. But, by inspecting the table, the reader can see that in each group all orders of the balls occur with equal frequency, so that it makes no difference whether they are drawn out in the order they were put in or not. Hence the colors of the balls already drawn have no influence on the probability of any other being white or black.

Now, if there be any way of enumerating the possibilities of Nature so as to make them equally probable, it is clearly one which should make one arrangement or combination of the elements of Nature as probable as another, that is, a distribution like that we have supposed, and it, therefore, appears that the assumption that any such thing can be done, leads simply to the conclusion that reasoning from past to future experience is absolutely worthless. In fact, the moment that you assume that the chances in favor of that of which we are totally ignorant are even, the problem about the tides does not differ, in any arithmetical particular, from the case in which a penny (known to be equally likely to come up heads and tails) should turn up heads m times successively. In short, it would be to assume that Nature is a pure chaos, or chance combination of independent elements, in which reasoning from one fact to another would be impossible; and since, as we shall hereafter see, there is no judgment of pure observation without reasoning, it would be to suppose all human cognition illusory and no real knowledge possible. It would be to suppose that if we have found the order of Nature more or less regular in the past, this has been by a pure run of luck which we may expect is now at an end. Now, it may be we have no scintilla of proof to the contrary, but reason is unnecessary in reference to that belief which is of all the most settled, which nobody doubts or can doubt, and which he who should deny would stultify himself in so doing.

The relative probability of this or that arrangement of Nature is something which we should have a right to talk about if universes were as plenty as blackberries, if we could put a quantity of them in a bag, shake them well up, draw out a sample, and examine them to see what proportion of them had one arrangement and what proportion another. But, even in that case, a higher universe would contain us, in regard to whose arrangements the conception of probability could have no applicability.

IV.

We have examined the problem proposed by the conceptualists, which, translated into clear language, is this: Given a synthetic conclusion; required to know out of all possible states of things how many will accord, to any assigned extent, with this conclusion; and we have found that it is only an absurd attempt to reduce synthetic to analytic reason, and that no definite solution is possible.

But there is another problem in connection with this subject. It

is this: Given a certain state of things, required to know what proportion of all synthetic inferences relating to it will be true within a given degree of approximation. Now, there is no difficulty about this problem (except for its mathematical complication); it has been much studied, and the answer is perfectly well known. And is not this, after all, what we want to know much rather than the other? Why should we want to know the probability that the fact will accord with our conclusion? That implies that we are interested in all possible worlds, and not merely the one in which we find ourselves placed. Why is it not much more to the purpose to know the probability that our conclusion will accord with the fact? One of these questions is the first above stated and the other the second, and I ask the reader whether, if people, instead of using the word probability without any clear apprehension of their own meaning, had always spoken of relative frequency, they could have failed to see that what they wanted was not to follow along the synthetic procedure with an analytic one, in order to find the probability of the conclusion; but, on the contrary, to begin with the fact at which the synthetic inference aims, and follow back to the facts it uses for premises in order to see the probability of their being such as will yield the truth.

As we cannot have an urn with an infinite number of balls to represent the inexhaustibleness of Nature, let us suppose one with a finite number, each ball being thrown back into the urn after being drawn out, so that there is no exhaustion of them. Suppose one ball out of three is white and the rest black, and that four balls are drawn. Then the table on page 713 represents the relative frequency of the different ways in which these balls might be drawn. It will be seen that if we should judge by these four balls of the proportion in the urn, 32 times out of 81 we should find it $\frac{1}{4}$, and 24 times out of 81 we should find it $\frac{1}{3}$, the truth being $\frac{1}{3}$. To extend this table to high numbers would be great labor, but the mathematicians have found some ingenious ways of reckoning what the numbers would be. It is found that, if the true proportion of white balls is p, and s balls are drawn, then the error of the proportion obtained by the induction will be—

half the time within	$0.477\sqrt{\frac{2p(1-p)}{s}}$
9 times out of 10 within	$1.163\sqrt{\frac{2p(1-p)}{s}}$
99 times out of 100 within	$1.821\sqrt{\frac{2p(1-p)}{s}}$
999 times out of 1,000 within	$2.328\sqrt{\frac{2p(1-p)}{s}}$
9,999 times out of 10,000 within	$2.751\sqrt{\frac{2p(1-p)}{s}}$
9,999,999,999 times out of 10,000,000,000 within	$4.77\sqrt{\frac{2p(1-p)}{s}}$

The use of this may be illustrated by an example. By the census of 1870, it appears that the proportion of males among native white children under one year old was 0.5082, while among colored children of the same age the proportion was only 0.4977. The difference between these is 0.0105, or about one in a 100. Can this be attributed to chance, or would the difference always exist among a great number of white and colored children under like circumstances? Here p may be taken at $\frac{1}{2}$; hence $2p\ (1-p)$ is also $\frac{1}{2}$. The number of white children counted was near 1,000,000; hence the fraction whose square-root is to be taken is about $\frac{1}{2000000}$. The root is about $\frac{1}{1400}$, and this multiplied by 0.477 gives about 0.0003 as the probable error in the ratio of males among the whites as obtained from the induction. The number of black children was about 150,000, which gives 0.0008 for the probable error. We see that the actual discrepancy is ten times the sum of these, and such a result would happen, according to our table, only once out of 10,000,000,000 censuses, in the long run.

It may be remarked that when the real value of the probability sought inductively is either very large or very small, the reasoning is more secure. Thus, suppose there were in reality one white ball in 100 in a certain urn, and we were to judge of the number by 100 drawings. The probability of drawing no white ball would be $\frac{366}{1000}$; that of drawing one white ball would be $\frac{370}{1000}$; that of drawing two would be $\frac{185}{1000}$; that of drawing three would be $\frac{61}{1000}$; that of drawing four would be $\frac{15}{1000}$; that of drawing five would be only $\frac{3}{1000}$, etc. Thus we should be tolerably certain of not being in error by more than one ball in 100.

It appears, then, that in one sense we can, and in another we cannot, determine the probability of synthetic inference. When I reason in this way:

Ninety-nine Cretans in a hundred are liars;

But Epimenides is a Cretan;

Therefore, Epimenides is a liar:—

I know that reasoning similar to that would carry truth 99 times in 100. But when I reason in the opposite direction:

Minos, Sarpedon, Rhadamanthus, Deucalion, and Epimenides, are all the Cretans I can think of;

But these were all atrocious liars,

Therefore, pretty much all Cretans must have been liars;

I do not in the least know how often such reasoning would carry me right. On the other hand, what I do know is that some definite proportion of Cretans must have been liars, and that this proportion can be probably approximated to by an induction from five or six instances. Even in the worst case for the probability of such an inference, that in which about half the Cretans are liars, the ratio so obtained would probably not be in error by more than $\frac{1}{7}$. So much

I know; but, then, in the present case the inference is that pretty much all Cretans are liars, and whether there may not be a special improbability in that I do not know.

V.

Late in the last century, Immanuel Kant asked the question, "How are synthetical judgments *a priori* possible?" By synthetical judgments he meant such as assert positive fact and are not mere affairs of arrangement; in short, judgments of the kind which synthetical reasoning produces, and which analytic reasoning cannot yield. By *a priori* judgments he meant such as that all outward objects are in space, every event has a cause, etc., propositions which according to him can never be inferred from experience. Not so much by his answer to this question as by the mere asking of it, the current philosophy of that time was shattered and destroyed, and a new epoch in its history was begun. But before asking *that* question he ought to have asked the more general one, "How are any synthetical judgments at all possible?" How is it that a man can observe one fact and straightway pronounce judgment concerning another different fact not involved in the first? Such reasoning, as we have seen, has, at least in the usual sense of the phrase, no definite probability; how, then, can it add to our knowledge? This is a strange paradox; the Abbé Gratry says it is a miracle, and that every true induction is an immediate inspiration from on high.[1] I respect this explanation far more than many a pedantic attempt to solve the question by some juggle with probabilities, with the forms of syllogism, or what not. I respect it because it shows an appreciation of the depth of the problem, because it assigns an adequate cause, and because it is intimately connected—as the true account should be—with a general philosophy of the universe. At the same time, I do not accept this explanation, because an explanation should tell *how* a thing is done, and to assert a perpetual miracle seems to be an abandonment of all hope of doing that, without sufficient justification.

It will be interesting to see how the answer which Kant gave to his question about synthetical judgments *a priori* will appear if extended to the question of synthetical judgments in general. That answer is, that synthetical judgments *a priori* are possible because whatever is universally true is involved in the conditions of experience. Let us apply this to a general synthetical reasoning. I take from a bag a handful of beans; they are all purple, and I infer that all the beans in the bag are purple. How can I do that? Why, upon the principle that whatever is universally true of my experience (which

[1] *Logique.* The same is true, according to him, of every performance of a differentiation, but not of integration. He does not tell us whether it is the supernatural assistance which makes the former process so much the easier.

is here the appearance of these different beans) is involved in the condition of experience. The condition of this special experience is that all these beans were taken from that bag. According to Kant's principle, then, whatever is found true of all the beans drawn from the bag must find its explanation in some peculiarity of the contents of the bag. This is a satisfactory statement of the principle of induction.

When we draw a deductive or analytic conclusion, our rule of inference is that facts of a certain general character are either invariably or in a certain proportion of cases accompanied by facts of another general character. Then our premise being a fact of the former class, we infer with certainty or with the appropriate degree of probability the existence of a fact of the second class. But the rule for synthetic inference is of a different kind. When we sample a bag of beans we do not in the least assume that the fact of some beans being purple involves the necessity or even the probability of other beans being so. On the contrary, the conceptualistic method of treating probabilities, which really amounts simply to the deductive treatment of them, when rightly carried out leads to the result that a synthetic inference has just an even chance in its favor, or in other words is absolutely worthless. The color of one bean is entirely independent of that of another. But synthetic inference is founded upon a classification of facts, not according to their characters, but according to the manner of obtaining them. Its rule is, that a number of facts obtained in a given way will in general more or less resemble other facts obtained in the same way; or, *experiences whose conditions are the same will have the same general characters.*

In the former case, we know that premises precisely similar in form to those of the given ones will yield true conclusions, just once in a calculable number of times. In the latter case, we only know that premises obtained under circumstances similar to the given ones (though perhaps themselves very different) will yield true conclusions, at least once in a calculable number of times. We may express this by saying that in the case of analytic inference we know the probability of our conclusion (if the premises are true), but in the case of synthetic inferences we only know the degree of trustworthiness of our proceeding. As all knowledge comes from synthetic inference, we must equally infer that all human certainty consists merely in our knowing that the processes by which our knowledge has been derived are such as must generally have led to true conclusions.

Though a synthetic inference cannot by any means be reduced to deduction, yet that the rule of induction will hold good in the long run may be deduced from the principle that reality is only the object of the final opinion to which sufficient investigation would lead. That belief gradually tends to fix itself under the influence of inquiry is, indeed, one of the facts with which logic sets out.

ON EDISON'S TALKING-MACHINE.[1]

By ALFRED M. MAYER.

MR. THOMAS A. EDISON has recently invented an instrument which is undoubtedly the acoustic marvel of the century. It is called the "Speaking Phonograph," or, adopting the Indian idiom, one may aptly call it "*The Sound-Writer who talks.*" Much curiosity has been expressed as to the workings of this instrument, so I purpose giving an account of it.

All talking-machines may be reduced to two types. That of Prof. Faber, of Vienna, is the most perfect example of one type; that of Mr. Edison is the only example of the other.

Faber worked at the source of articulate sounds, and built up an artificial organ of speech, whose parts, as nearly as possible, perform the same functions as corresponding organs in our vocal apparatus. A vibrating ivory reed, of variable pitch, forms its vocal chords. There is an oral cavity, whose size and shape can be rapidly changed by depressing the keys on a key-board. A rubber tongue and lips make the consonants; a little windmill, turning in its throat, rolls the letter *R*, and a tube is attached to its nose when it speaks French. This is the anatomy of this really wonderful piece of mechanism.

Faber attacked the problem on its physiological side. Quite differently works Mr. Edison: he attacks the problem, not at the source of origin of the vibrations which make articulate speech, but, considering these vibrations as already made, it matters not how, he makes these vibrations impress themselves on a sheet of metallic foil, and then reproduces from these impressions the sonorous vibrations which made them.

Faber solved the problem by reproducing the mechanical *causes* of the vibrations making voice and speech; Edison solved it by obtaining the mechanical *effects* of these vibrations. Faber reproduced the movements of our vocal organs; Edison reproduced the motions which the drum-skin of the ear has when this organ is acted on by the vibrations *caused* by the movements of the vocal organs.

Figs. 1 and 2 will render intelligible the construction of Mr. Edison's machine. A cylinder, *F*, turns on an axle which passes through the two standards, *A* and *B*. On one end of this axle is the crank, *D*; on the other the fly-wheel, *E*. The portion of this axle to the right of the cylinder has a screw-thread cut on it, which, working in a nut, *A*, causes the cylinder to move laterally when the crank is

[1] The figures in this article are taken from "Sound, a Series of Simple, Entertaining, and Inexpensive Experiments in the Phenomena of Sound, for the Use of Students of every Age." By Alfred M. Mayer. Vol. ii. of "Experimental Science Series for Beginners." (Now in press and soon to be published by D. Appleton & Co.)

turned. On the surface of the cylinder is scored the same thread as on its axle. At *F* (shown in one-half scale in Fig. 2) is a plate of iron, *A*, about $\frac{1}{100}$ of an inch thick. This plate can be moved toward and from the cylinder by pushing in or pulling out the lever *H G*, which turns in an horizontal plane around the pin *I*.

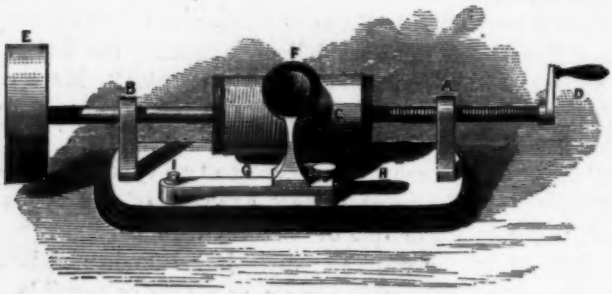

FIG. 1.—EDISON'S TALKING-PHONOGRAPH.

The under side of this thin iron plate, *A* (Fig. 2), presses against short pieces of rubber tubing, *X* and *X*, which lie between the plate and a spring attached to *E*. The end of this spring carries a rounded steel point, *P*, which enters slightly between the threads scored on the cylinder *C*. The distance of this point, *P*, from the cylinder is regulated by a set-screw, *S*, against which abuts the lever, *H G*. Over the iron plate, *A*, is a disk of vulcanite, *B B*, with a hole in its centre. The under side of this disk nearly touches the plate *A*. Its upper surface is cut into a shallow, funnel-shaped cavity, leading to the opening in its centre.

To operate this machine, we first neatly coat the cylinder with a sheet of foil, made to adhere by gumming the corners; then we bring the point, *P*, to bear against this foil, so that, on turning the cylinder, it makes a depressed line, or furrow. The mouth is now placed close to the opening in the vulcanite disk, *B B*, and *the metal plate is talked to* while the cylinder is revolved with a uniform motion.

The plate, *A*, vibrates to the voice, and the point, *P*, indents the foil, impressing in it the varying numbers, amplitudes, and durations, of these vibrations. If the vibrations given by the voice are those causing simple sounds, and are of a uniform, regular character, then similar, regular, undulating depressions are made in the foil. If the vibrations are those causing complex and irregular sounds (like those of the voice in speaking), then, similarly, the depressions made in the foil are complex, having profiles like the curve, *B*, in Fig. 3. Thus the yielding and inelastic foil receives and *retains* the mechanical impressions of these vibrations with all their minute and subtile characteristics.

The permanent impressions of the vibrations of the voice are now

made. It remains *to obtain from these impressions the aërial vibrations which made them.* Nothing is simpler. The plate *A*, with its point, *P*, is moved away from the cylinder by pulling toward you the lever *H G*. Then the motion of the cylinder is reversed till you have brought opposite to the point *P* the beginning of the series of impressions which it has made on the foil. Now bring the point up

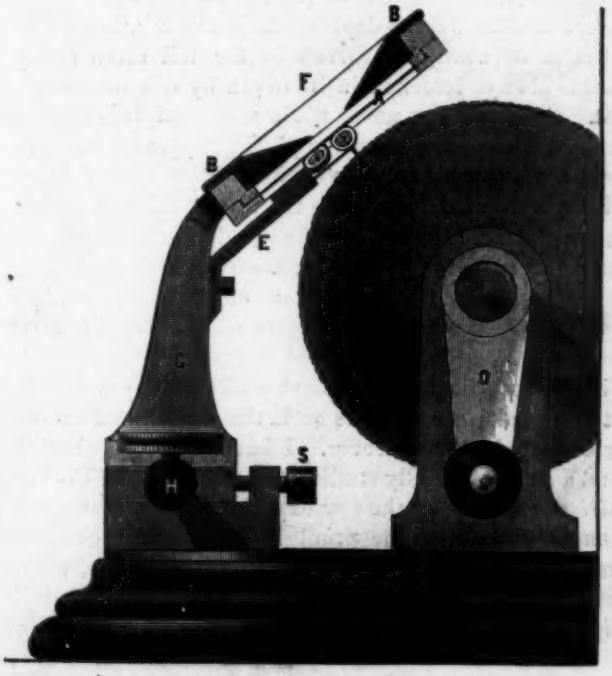

FIG. 2.

to the cylinder; place against the vulcanite plate, *B B*, a large cone of paper or tin to reënforce the sounds, and then steadily turn the crank *D*. The elevatiops and depressions which have been made by the point *P* now pass under this point, and in so doing they cause it and the thin iron plate to make over again the precise vibrations which animated them when they made these impressions under the action of the voice. The consequence of this is, that the iron plate gives out the vibrations which previously fell upon it, and it *talks back to you what you said to it.*

By the following method we have just obtained several magnified traces on smoked glass of the contour, or profile, of the elevations and depressions made in the foil by the sonorous vibrations. On the under side of the shorter arm of a delicate lever is a point, made as nearly as possible like the point *P* under the thin iron plate *A*. Cemented to

the end of the longer arm of this lever is a pointed slip of thin copper-foil, which just touched the vertical surface of a smoked-glass plate. The point on the short arm of the lever rested in the furrow in which are the depressions and elevations made in the foil on the cylinder. Rotating the cylinder with a slow and uniform motion, while the plate of glass was slid along, the point of copper-foil scraped the lampblack off the smoked-glass plate and traced on it the magnified profile of the depressions and elevations in the foil on the cylinder. I say expressly *elevations* as well as depressions in the foil, because, when the plate vibrates outward, the furrow in the foil often entirely disappears, and is always lessened in its depth by this outward motion of the point. One who has never made a special investigation of the character of the impressions on the phonograph, and forms his opinion from their appearance to his eye, might state that they are simply dots and dashes, like the marks on the filet of a Morse instrument.

Another method of obtaining the profile of the impressions on the foil is to back it with an easily-fusible substance, and then, cutting through the middle of the furrows, we obtain a section, in which the edge of the foil presents to us the form of the elevations and depressions.

The instrument has been so short a time in my possession, that I have not had the leisure to make on it the careful and extended series of experiments which it deserves. I have, however, obtained several traces, and I have especially studied the characters of the trace of the sound of *bat*. As far as the few experiments warrant an expression of opinion, it seems that the profile of the impressions made on the phonograph and the contours of the flames of König, when vibrated by the same compound sound, bear a close resemblance.

In Fig. 3 we give on line *A* the appearance to the eye of the im-

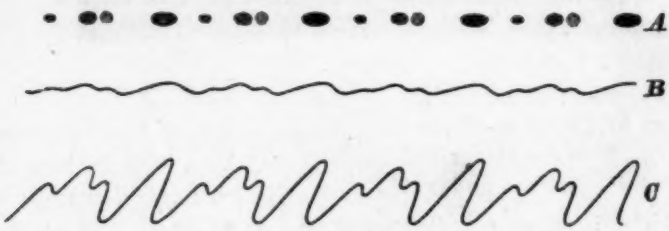

FIG. 3.

pressions on the foil, when the sound of *a* in *bat* is sung against the iron plate of the phonograph. *B* is the magnified profile of these impressions on the smoked glass obtained as described above. *C* gives the appearance of König's flame when the same sound is sung quite close to its membrane. I say expressly *quite close* to its membrane, for the form of the trace obtained from a point attached to a membrane vibrating under the influence of a compound sound depends on

the *distance* of the source of the sound from the membrane, and the same compound sound will form an infinite number of different traces as we gradually increase the distance of its place of origin from the membrane; for, as you increase this distance, the waves of the components of the compound sound are made to strike on the membrane at different periods of their swings.

For example, if the compound sound is formed of six harmonics, the removal of the source of the sonorous vibrations, from the membrane to a distance equal to $\frac{1}{4}$ of a wave-length of the 1st harmonic, will remove the 2d, 3d, 4th, 5th, and 6th harmonics to distances from the membrane equal respectively to $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, and $1\frac{1}{2}$ wave-lengths. The consequence evidently is, that the resultant wave-form is entirely changed by this motion of the source of the sound, though the sonorous sensation of the compound sound remains unchanged.

The above facts are readily proved experimentally by sending a constant compound sound into the cone of König's apparatus, while we gradually lengthen the tube between the cone and the membrane next to the flame. This is best done by the intervention of one tube sliding in another, like a trombone. These experiments I have recently made with entire success, and they explain the discussions which have arisen between different observers as to the composition of vocal and other composite sounds, as analyzed by means of König's vibrating flames.

These facts also show how futile it is for any one to hope to be able to *read* the impressions and traces of phonographs, for these traces will vary, not alone with the quality of the voices, but also with the differently-related times of starting of the harmonics of these voices, and with the different relative intensities of these harmonics.

It is necessary to give to the cylinder a very regular motion of rotation while it receives and reproduces the vibrations made in singing; for even slight irregularities in the velocity of the cylinder destroy the accuracy of the musical intervals, and cause the phonograph to sing falsetto. Even the reproducing of speech is greatly improved by rotating the cylinder by mechanism which gives it uniformity of motion. If you make the machine talk by giving it a more rapid rotation than it had when you spoke to it, the pitch of its voice is raised; and by varying the velocity of the cylinder the machine may be made to speak the same sentence in a very bass voice, or in a voice of a pitch so high that its sounds are really elfish and entirely unnatural.

Recent experiments seem to show that the nearer the diaphragm *A* approaches to the construction of the drum-skin of the human ear by "damping" it, as the hammer-bone does the latter, the better does it record and repeat the sonorous vibrations; for the motion of a membrane thus damped is ruled alone by the aërial vibrations falling on it.

Mr. Edison has just sent me the following notes of the results of recent experiments:

"That the size of the hole through which you speak has a great deal to do with the articulation. When words are spoken against the whole diaphragm, the hissing sounds, as in *shall*, *fleece*, *last*, are lost; whereas, by the use of a small hole provided with sharp edges, these words are reënforced and recorded. Also, teeth around the edge of a slot, instead of a round hole, give the hissing consonants clearer.

"That the best reading is obtained when the mouth-piece, *B F B* (Fig. 2), is covered with several thicknesses of cloth, so that the snapping noise on the foil is rendered less audible.

"I send you a sheet of copper-foil upon which I made records in Ansonia, Connecticut, that could be read 275 feet in the open air, and perhaps farther, if it had been tried."

Mr. Edison also states that impressions of sonorous vibrations have been made on a cylinder of soft Norway iron, and from these impressions have been reproduced the sonorous vibrations which made them.

THE MARPINGEN MIRACLES.

THE recent debate in the Lower House of the Prussian Parliament on the Marpingen miracles is in many ways remarkable. That the Ultramontane party should have had the courage themselves to force on the discussion is rather surprising, though it is true that all the speakers on that side were careful to deprecate the notion of attaching any religious importance to the question, and to treat it purely as one of law and equity, while they studiously avoided committing themselves to any belief in the alleged supernatural occurrences. Before, however, speaking of the debate, we may recall to the memory of our readers the circumstances which gave rise to it, and which occurred a year and a half ago in the month of July, 1876. And in doing so it may be well to repeat what we have before now had occasion to observe in dealing with narratives of this kind, that there is no need to enter on any general discussion of the existence or credibility of miraculous agency. There is certainly, to use Mr. Lecky's words, "no contradiction involved in the belief that spiritual beings of power and wisdom immeasurably transcending our own exist, or that, existing, they might, by the normal exercise of their powers, perform feats as far surpassing the understanding of the most gifted of mankind as the electric telegraph and the prediction of an eclipse surpass the faculties of a savage." Thus much would indeed be contended for by every Christian apologist, nor is it consistent to maintain the truth of the New Testament miracles and deny on *a priori*

grounds the possibility or actual occurrence of any subsequent phenomena of the kind. That is a question of evidence, and, as Mr. Lecky goes on to observe, "very few of the minor facts of history are authenticated by as much evidence as" some of those later miracles which he specifies, to one of which, by no means a favorite with Ultramontanes, we may have occasion to refer presently. But there are few subjects on which ordinary persons, even educated persons, have such loose notions as on the true nature of evidence, or where the wish, whether it be an innate feeling of sympathy or of antipathy, is so apt to become father to the thought. And now we may proceed without further preface to reproduce the main details of the marvelous tale brought from Marpingen, a village in Rhenish Prussia, in July, 1876, and which formed the text of a long debate in the Prussian Parliament a fortnight ago.

It appears that on two successive days, July 3d and 4th, three little girls of the village of Marpingen announced that they had seen the Virgin with her infant Son, sitting on the ground in a neighboring wood, and on the second of these days she replied to their questions, "I am she who was conceived without sin, and you should pray and pray forever." On the third day the apparition was again visible and discoursed to the children for some time, while a crowd, who had followed them from the village kept apart reverentially from the hallowed spot, *the apparition being visible and audible to the three little girls only.* It was explained that this peculiar privilege was vouchsafed to them because they were "the only innocent persons in the wood," and the apparition expressly declined to see any of the neighboring priests, but *ordered a chapel to be built on the spot from the proceeds of a public subscription.* She finally, at their request, permitted an invalid to be brought by the children to touch her feet, though he also never saw her, and he was instantly cured. After this crowds came to spend the night praying and singing in the wood, two or three of whom declared that they saw the Virgin amid the trees, and the children were kept constantly employed in laying the hands of the sick on the feet of the invisible figure. They apparently, however, found this burden too great for them, for a few days later they announced that the water of a neighboring spring had been endowed with miraculous properties, and might be conveyed to those who were unable to come themselves, and thenceforth the concourse of pilgrims increased. Hereupon the civil authorities interfered, whether on account of disturbances caused by the multitudes who congregated in the forest, or from a fear that the miracle was intended to be utilized for purposes of agitation against the Government. On July 13th, ten days after the first apparition, the Burgomaster of Marpingen ordered the people to leave the wood, and on their refusal had it cleared by the military; from that time it was guarded by police and soldiers quartered in the village, where the inhabitants complain that forced requisitions were

made on them, and the place treated as though occupied by a hostile army. It was a formal motion for the repayment to the commune of the 4,000 marks (about £200) said to have been thus levied on it, and for the reprimand of the local magistrates for harsh and arbitrary conduct, that led to the debate in the Prussian Parliament. It should be added that the three little girls and a priest of the district were arrested on suspicion of religious fraud, but eventually released for lack of sufficient evidence, the girls stoutly denying that they had been inspired by either priest or parent. Entrance to the wood is still prohibited, but processions take place to the miraculous spring.

Now, the first observation that would occur to any one on reading this strange story is the conspicuous absence of anything like evidence of the alleged apparition, even putting aside the suspicion of deliberate fraud. The Madonna is visible to three little girls only, of about seven years of age, whose religious imagination might easily be excited, especially if they had heard of former apparitions of the same kind, as is more than probable. And when once they had committed themselves to the story—whether in simple piety or under some external influence—fear of consequences would alone secure their adhesion to it. But this leads us on to another and more important comment, which will already have occurred to many of our readers, especially if they have taken note of the passages in the tale which we have italicized. The close resemblance in all its leading features to several former tales of miraculous apparition, and, above all, to the apparition at Lourdes, is too obvious and too minute to be considered accidental. Whether we suppose the whole affair to be an imposture pure and simple, as is likely enough, or whether we adopt the more charitable hypothesis of hallucination, there can hardly be a doubt that the Lourdes miracle suggested the incidents of the Marpingen one. In both cases, as before at La Salette, young children are the sole witnesses of the marvel; in both cases it is the Virgin who appears, and, while at Lourdes she oddly describes herself as being "the Immaculate Conception," at Marpingen the more grammatical formula is adopted, "I am she who was conceived without sin;" in both cases multitudes follow the children, but are obliged to take on faith what to them, and to them alone, is matter of sight and hearing; in both cases, and this is significant, the Madonna expressly directs a chapel to be built on the spot, and that indeed appears to be the chief object of the apparition; and, lastly, in both cases a miraculous spring is either created or disclosed. On this last point we have another word to say. It is of course argued by the defenders of these miracles, and is in fact the only plausible argument left to them, that whatever becomes of the evidence of the children for the original tale —even though they should turn out afterward as the boy and girl at La Salette did turn out—there is no getting over the evidence of the miraculous cures. The reply is not far to seek. There might be, and

indeed are, examples of seemingly supernatural cures—we will mention one directly—attested by very strong evidence, but these are certainly not among them. Putting aside innumerable instances of failure and some of detected imposture which have been heard of in connection with Lourdes—it is too early yet to apply that test to Marpingen—it must never be forgotten how almost incalculable is the power of imagination over every kind especially of nervous disorder. There are unquestionably many persons of whom it may be said, in a different sense from that of the words as originally used, that "their faith has made them whole;" or, on the contrary, has made them ill. A ready instance comes to hand in connection with the recent hydrophobia scare. There can be no doubt that tetanus, which so closely simulates hydrophobia as often to be indistinguishable from it to all but adepts, may be and is produced by fear; and thus nervous persons who assume that a dog which bites them must be mad—though the chances are always really at least ten to one the other way—may easily give themselves a fatal disease without any external cause. On the other hand, a case was reported the other day from Italy, of a woman who was raving, as was supposed, from hydrophobia, but who promptly recovered on a miraculous relic being applied to her. The same explanation will cover innumerable cases, whether at Lourdes or elsewhere, of alleged miraculous cures. But we observed just now that there are examples on record of miraculous cures, the direct evidence of which is very striking. The late Sir James Stephen mentions one of them in these words: "The greatest genius, the most profound scholar, and the most eminent advocate of that age (the seventeenth century), all possessing the most ample means of knowledge, all carefully investigated, all admitted, and all defended with their pens, the miracle of the Holy Thorn. Europe at that time produced no three men more profoundly conversant with the laws of the material world, with the laws of the human mind, and with the municipal law, than Pascal, Arnauld, and Le Maître; and they were all sincere and earnest believers." Mr. Lecky similarly observes that few historical facts are so well authenticated as "the miracles of the Holy Thorn, or at the tomb of the Abbé Paris," which last, we may add, were attested among others by Voltaire. Be it so, but these are "Jansenist" miracles which Ultramontanes have always and scornfully refused to admit. The manifestations at the tomb of the Abbé Paris were actually suppressed by authority, ecclesiastical and civil, which suggested the famous epigram:

> "De par le roi, défense à Dieu
> De faire miracle en ce lieu."

Those who reject the far stronger evidence of these miracles must find some better argument than the alleged cures if they would have us accept the miraculous portents of Lourdes and Marpingen.

The debate in the Prussian Chamber was opened by Herr Bachem,

who insisted that the conduct of the authorities had been very reprehensible; even assuming the alleged miracles to be illusory or fraudulent, the sincere belief of the multitude ought to have been respected. Dr. Friedenthal, acting Minister of the Interior, replied:

"He was prepared to defend the action of the police, there being plenty of *prima-facie* evidence to show that the Marpingen miracle was a fraud. The alleged miracle happened in a district strongly infected by the Ultramontane movement, and previously productive of similar apparitions that had attracted the notice of the law. Early in 1875 a woman began to work miracles at Eppelborn, close to Marpingen, under the patronage of the local priest. She was convicted of fraud and sentenced to imprisonment. The same woman and the local priest who assisted her were subsequently again convicted of fraud, false pretenses, and gross immorality. The Marpingen miracle was no sooner bruited about than a school-girl at Groning, also near Marpingen, stated that she had had an audience of the Virgin. The girl was severely reprimanded by her father, when the visions ceased. At Berschweiler, likewise near Marpingen, no less than five persons between eleven and nineteen years of age, in 1876, professed to be in daily intercourse with the Virgin. A profitable trade in exorcisms, salvations from purgatory, and the like, having been opened by them, the authorities interfered. The police court eventually sent the whole gang to prison. At Gappenach a married couple were convicted of fraud for stating that they had seen the Virgin conversing with the three little girls in a bottle of Marpingen water. At Münchwies, district of Ottweiler, a couple of school-girls pretended to have interviews with the Virgin, until the parish priest objected to the story, when the apparitions ceased. Considering this excited condition of the province in which Marpingen is situate, and taking into account the peculiar character the Ultramontane movement had recently assumed in Germany, the authorities were perfectly justified in putting a stop to the Marpingen revival. There were 8,000 persons in the hallowed wood when the military were called in. Though there was some show of resistance, nobody was wounded. Subsequently the police appointed to watch the wood were fired at in the dark. With reference to the legal proceedings instituted by the crown, he, the minister, was in a position to say that a formal accusation would be preferred against certain persons supposed to be implicated in the Marpingen affair, when the character of the miracle would be fully investigated in open court."

To this statement Herr Lipke added that the three little girls, when first examined by the magistrate, professed to have seen not only the Virgin but the devil also, whom they described as "black and white"—the German national colors. He said that many Catholic priests with whom he had conversed on "the Marpingen swindle" agreed with him in disapproving it, and he thought the Ultramontanes had not benefited their cause by bringing the subject pefore Parliament. Another speaker on the same side, Judge Sello, admitted that some excesses had been committed by the troops, but the burgomaster who ordered them to clear the wood had been tried and fined in consequence. The debate was closed by Dr. Windthorst, the leader of the Ultramontane party, who declined to commit himself to the reality of the miracles, but complained that, as long as the Government kept

the see of Treves vacant, no proper investigation, as directed by the Council of Trent, could take place. Perhaps the legal investigation which is promised by Dr. Friedenthal may prove more efficacious in bringing the real facts to light. Meanwhile, it may be feared that belief in the Marpingen apparition will become a test question of Catholic orthodoxy in Germany, as belief in Lourdes and La Salette has long been a criterion for discriminating the *bien pensants* in France, in spite of the manly protests of some high authorities, such as Dupanloup, against this morbid craving for predictions and portents. We have never denied that German Catholics have a substantial grievance in the matter of the Falk laws, but they certainly will not improve their position with thinking men of any creed by adopting devices which can only escape graver censure if they are regarded as too silly to be dishonest.—*Saturday Review.*

THE SOURCE OF MUSCULAR POWER.

THE advance of modern research has brought the sciences of physics, chemistry, and physiology, into very close relations, and as the two former have given great help to the latter, many are looking to see all physiological problems finally resolved on physical and chemical principles. Much is to be expected from the future, but sanguine anticipations should not be allowed to misinterpret existing facts. Prof. Austin Flint, Jr., has been much occupied in investigating the living system as a dynamical engine, and has published the results of his experimental inquiries in a little volume, entitled "The Source of Muscular Power." He has made an important contribution to the subject of animal mechanics, and his views will be so interesting, alike to the physiologist and the general student, that a summary of his argument will be appreciated by the readers of the MONTHLY.

Since it has been ascertained that the force derived from chemical action which will raise the temperature of a pound of water 1° Fahr. will, under another form of manifestation, lift 772 pounds one foot high, 772 foot-pounds have been regarded as the force-equivalent of 1° of heat. In other words, if the burning or oxidation of a certain definite weight of matter will raise the temperature of one pound of water 1° Fahr., the force-value of this matter is said to be 772 foot-pounds.

In the animal economy, certain matters are taken in and consumed as food; matters are discharged from the body in the form of excretions, such as the constituents of the urine; a certain amount of heat is produced in the body in order to maintain the animal temperature, to supply the loss of heat dependent upon radiation from the surface; a

certain amount of force is exerted in the processes of circulation of the blood and in the respiratory movements, and a certain amount of work is performed by muscular action. If it be assumed that the oxidation of matter in the animal economy involves, of necessity, either the production of heat or of force, an answer to the following question becomes at once of great importance as regards our ideas of the immediate source of muscular power:

Is the food directly oxidized in the perfected and adult animal organism, the result of this oxidation being heat and force, and is this the single source of muscular power, or is the perfected animal organism, particularly as regards the muscular system, itself consumed gradually as a result of muscular work, the waste of muscular tissue being represented by the excretions, and such waste being repaired constantly by food? To state this question in simpler terms, is the muscular system a part of a machine that consumes food as fuel in the production of force, not wearing its own substance to any considerable extent, or does the muscular system use its own substance in the production of force?

Before 1866, the following ideas, formulated by Liebig, Lehmann, and others, were pretty generally accepted by physiologists:

The muscular substance, which constitutes about two-fifths of the weight of the entire body, is composed mainly of matters containing carbon, hydrogen, oxygen, and nitrogen, in contradistinction to the fats, which contain only carbon, hydrogen, and oxygen. The most important excrementitious matter thrown off by the kidneys is urea, which contains carbon, hydrogen, oxygen, and nitrogen. The amount of urea excreted is to be regarded, to a certain extent, as a measure of the physiological wear of the muscular system, which wear is increased by muscular exertion, there being a corresponding increase in the excretion of urea by the kidneys. This wear of the muscular system is being constantly repaired by the nitrogenized elements of food. In discussing, then, this question, physiologists have come to speak of the excretion of nitrogen as measuring, more or less accurately, the physiological wear of the muscular system.

In 1866, two German physiologists, Fick and Wislicenus, ascended one of the Alpine peaks, and measured the influence of this unusual muscular exertion upon the excretion of nitrogen. As it is well known that the quantity of nitrogenized food, such as meat, eggs, etc., influences the amount of nitrogen excreted by the kidneys, these observers confined themselves to a diet without nitrogen during the ascent and for a number of hours immediately preceding and following. They found that the amount of nitrogen eliminated by the kidneys was diminished during the muscular exertion by about one-third. From these experiments, they concluded that muscular exercise does not increase the elimination of nitrogen, but rather diminishes it; and from this time dates the proposition, which is now adopted by many

physiologists, that the muscular system is a machine which consumes food as fuel, and does not wear its own substance to any very great extent in the production of force. Fick and Wislicenus advanced the view that "the substances, by the burning of which force is generated in the muscles, are not the albuminous constituents of the tissues, but non-nitrogenous substances, either as fats or hydrates of carbon."

Such a doctrine as that advanced by Fick and Wislicenus, according to Prof. Flint, is not logical and is opposed to many well-known physiological facts. The arguments he advances against it are the following:

1. Physiological experiments should be made under strictly natural or physiological conditions of the system. A non-nitrogenized diet is not natural. No man would attempt to perform a feat of muscular endurance under a diet composed exclusively of fat, starch, and sugar, which was the exclusive diet of Fick and Wislicenus.

2. Lehmann has shown that an exclusively non-nitrogenized diet, of itself, without any variation in muscular exercise, will reduce the excretion of nitrogen by the kidneys more than one-half. Pavy has shown the same effects of non-nitrogenized food upon the system without any variation in muscular exercise.

3. Fick and Wislicenus do not show that extraordinary muscular exertion, with a non-nitrogenized diet, diminishes the excretion of nitrogen below the point to which it would be reduced by the diet itself, without muscular work; for they made no comparative experiments with a non-nitrogenized diet and no unusual exercise.

In view of these facts, the conclusion arrived at by Prof. Flint is, that the experiments of Fick and Wislicenus fail to show that muscular exercise diminishes, or even does not increase, the elimination of nitrogen, which is the very essence of their argument.

In 1870, Prof. Flint made a series of elaborate experiments upon Weston, during a walk of three hundred and seventeen and one-half miles in five consecutive days. Recognizing the fact that the elimination of nitrogen bears a certain relation to the nitrogen of the food, in these experiments, Prof. Flint estimated the nitrogen of the food and calculated the proportion of nitrogen excreted to the nitrogen ingested, which had never been done in any previous experiments upon the physiological effects of muscular exercise. His observations were continued for five days before the walk, the five days of the walk, and five days after the walk. Prof. Flint, or his assistants, were with Weston, day and night, for the entire fifteen days. Every article of food was weighed or measured, and its nitrogen carefully estimated, as was the nitrogen excreted. The variations in body-weight, temperature, etc., were also taken. No accident occurred, and the observations were absolutely complete. The most important general results of these experiments were the following:

For the five days before the walk, the average daily exercise being

eight and one-fifth miles, the average proportionate excretion of nitrogen by the kidneys was 86.58 parts for every 100 parts of nitrogen of food.

For the five days of the walk, the average daily exercise being sixty-three and one-half miles, the average proportionate excretion of nitrogen by the kidneys was 143.98 parts for every 100 parts of nitrogen of food.

For the five days after the walk, the average daily exercise being two and one-fifth miles, the average proportionate excretion of nitrogen by the kidneys was 77.03 parts for every 100 parts of nitrogen of food.

These facts showed conclusively that, in this instance, at least, the extraordinary exertion of walking three hundred and seventeen and one-half miles in five consecutive days very largely increased the proportionate excretion of nitrogen by the kidneys.

The source of the excess of nitrogen excreted during the walk must have been the excessive wear of muscular tissue engendered by the extraordinary exertion, which was not repaired by the food. This is rendered almost certain by the following calculation:

At the beginning of the walk, Weston was in good condition, with little or no fat, and he weighed 119.20 pounds. "At the end of the five days' walk, the weight had been reduced from 119.20 to 115.75 pounds, showing a loss of 3.45 pounds. According to Payen, three parts of nitrogen represent one hundred parts of fresh muscular tissue. The total quantity of nitrogen discharged during these five days was 1,811.62 grains. The total nitrogen of food during the same period amounted to 1,173.82 grains, giving an excess of 637.80 grains of nitrogen discharged over the nitrogen of food. The 637.80 grains of nitrogen, according to Payen's formula, would represent 21,260.00 grains, or 3.037 pounds of muscular tissue. The actual loss of muscular tissue was 3.45 pounds, and the loss unaccounted for, amounting to only 0.413 of a pound, is very small. It might be fat or water, or the difference might be due to inaccuracies in the estimates of the nitrogen of food, which, of necessity, were approximative."

In 1876, Dr. Pavy, of London, made a series of experiments upon Perkins, a pedestrian, and upon Weston, similar to those made by Prof. Flint upon Weston, in 1870. The following were the general results of these observations:

Perkins walked sixty-five and one-half miles in twenty-four hours. During this time, he excreted 190.37 parts of nitrogen by the kidneys for every 100 parts of nitrogen of food. For twenty-four hours of rest, several days after this walk, Perkins excreted 76.58 parts of nitrogen by the kidneys for every 100 parts of nitrogen of food.

Observations were made upon Weston for eleven days of walking, as follows: 1. A walk of one hundred and eighty and one-half miles in two consecutive days; 2. A walk of two hundred and sixty-three

miles in seventy-five consecutive hours; 3. A walk of four hundred and fifty miles in six consecutive days. The proportionate excretion of nitrogen was estimated for these periods of exercise, and was also calculated for eight days of rest. The daily average excretion of nitrogen for the eight days of rest was 60.90 parts for every 100 parts of nitrogen of food. The daily average excretion of nitrogen for the eleven days of walking was 87.34 parts for every 100 parts of nitrogen of food—an increased proportion of 43.44 per cent. These experiments, like those of Prof. Flint, show a very great increase in the proportionate excretion of nitrogen produced by the excessive and prolonged muscular exertion.

Dr. Pavy admits, as the result of his own experiments, the simple fact that muscular exercise increases the proportionate excretion of nitrogen, but he does not accept the view advanced by Prof. Flint, that the muscular system, in exerting force, consumes its own substance, and that this substance is repaired by food. Dr. Pavy made a series of calculations, in connection with his experiments, comparing the force-value of the excess of nitrogen excreted during exercise over the nitrogen excreted during rest with the work actually performed in walking. He attempted to show that the force represented by this excess of nitrogen excreted would not account for the work accomplished. These calculations of Dr. Pavy involve formulæ for reducing miles walked to foot-pounds, and estimates of the force exerted in respiratory movements, the action of the heart, etc. Prof. Flint, in his essay, gives an elaborate review of these calculations, and objects to many of the formulæ as necessarily inaccurate. It is impossible, in a short abstract, to give a satisfactory account of Prof. Flint's argument upon these points. The following are the conclusions arrived at by Prof. Flint, as the result of the various experiments which he has discussed:

"I. While the various elements of food burned in oxygen out of the body will produce a definite amount of heat which may be calculated as equivalent to a definite number of foot-pounds of force, the application of this law to the changes which food or certain of the constituents of the body undergo in the living organism is uncertain and unsatisfactory, for the following reasons:

"(*a.*) There is no proof that the elements of food undergo the same changes in the living body as when burned in oxygen, or that definite amounts of heat or force are necessarily manifested by their metamorphoses in such a way that they can be accurately measured.

"(*b.*) Assuming that the elements of food contain a definite amount of locked-up force, to measure the part of this force which is expended in muscular work, it is indispensable to be able to estimate accurately the force used in circulation, respiration, and the various nutritive processes, and to measure the heat evolved which maintains the standard animal temperature and which compensates the heat lost by evaporation from the general surface. It does not seem that any accurate idea can be formed of the amount of force used in circulation and respiration, and the estimates made by different observers of authority

present variations sometimes of more than one hundred per cent. Such estimates are usually made in view of some dynamic theory, and they are based upon physiological data which are necessarily uncertain and subject to wide and frequent variations. No approximate estimate, even, can be made of the actual amount of heat produced within the living organism, except, perhaps, during a condition of nearly absolute muscular repose. The only way in which this could be done would be to deduct the force used in muscular work, circulation, respiration, and the nutritive processes, from the heat-value or force-value of the food. These elements of the question being uncertain, an accurate estimate of the heat produced becomes impossible, as, at the best, the only definite quantity in the problem is the total heat-value or force-value of food.

"(*c.*) To compare an amount of muscular work actually performed with the estimated force-value of food, apart from the impossibility of arriving at an accurate estimate of the amount of food consumed in circulation, respiration, the nutritive processes, and the production of heat, which is a necessary element in the problem, the work actually performed in walking a certain distance must be reduced to foot-pounds or foot-tons. The formula for this is so uncertain that no such reduction can be made which can be assumed to be even approximatively correct.

"II. The method of calculating the possible amount of force of which the body is capable, by using as the sole basis for this calculation the force-value of food, must be abandoned until the various necessary elements of the problem can be made sufficiently accurate to accord with the results of experiments upon the living body. Until that time arrives, physiologists should rely upon the positive results obtained by experiments rather than upon calculations made from uncertain data and under the influence of special theories. In case of fatal disagreement between any theory and definite experimental facts, the theory must be abandoned, provided the facts be incontestable.

"III. Experiments show that the estimated force-value of food, after deducting the estimated force used in circulation, respiration, the nutritive processes, and in the production of heat, will sometimes account for a small fraction only of muscular work actually performed, this work being reduced to foot-tons by the uncertain process to which I have already alluded. The errors in these calculations are manifestly so considerable that the calculated results seem to be of little value, while the experimental fact that a certain amount of work has been accomplished must remain.

"IV. It must be admitted that, under ordinary and normal conditions of diet and muscular exercise, the weight of the body being uniform, the ingress and egress of matter necessarily balance each other. If this balance be disturbed by diminishing the supply of food below the requirements of the system for its nutrition and for muscular work, the body necessarily loses weight, a certain portion of its constituent parts being consumed and not repaired. If the balance be disturbed by increasing the muscular work to the maximum of endurance and beyond the possibility of complete repair by food, the body loses weight. The probable source of muscular power may be most easily and satisfactorily studied by disturbing the balance between consumption and repair by increasing the work. In this, it is rational to assume that the processes of physiological wear of the tissues are not modified in kind, but simply in degree of activity.

"V. Experiments show that excessive and prolonged muscular exercise may increase the waste or wear of certain of the constituents of the body to such a degree that this wear is not repaired by food. Under these conditions, there is an increased discharge of nitrogen, particularly in the urine. This waste of

tissue may be repaired if food can be assimilated in sufficient quantity, but in my experiments it was not repaired. The most important question to determine experimentally in this connection is with regard to the influence of excessive and prolonged muscular exercise upon the excretion of nitrogen. It is shown experimentally that such exercise always increases the excretion of nitrogen to a very marked degree, under normal conditions of alimentation; but the proportionate quantity to the nitrogen of food is great when the nitrogen of food remains the same as at rest, and is not so great, naturally, when the nitrogen of food is increased. In the latter case, the excessive waste of the tissues is in part, or it may be wholly, repaired by the increased quantity of food. Experiments upon excessive exertion with a non-nitrogenous diet are made under conditions of the system that are not physiological; and the want of nitrogen in the food in such observations satisfactorily accounts for the diminished excretion of nitrogen.

"VI. By systematic exercise of the general muscular system or of particular muscles, with proper intervals of repose for repair and growth, muscles may be developed in size, hardness, power, and endurance. The only reasonable theory that can be offered in explanation of this process is the following: While exercise increases the activity of disassimilation of the muscular substance, a necessary accompaniment of this is an increased activity in the circulation in the muscles, for the purpose of removing the products of their physiological wear. This increased activity of the circulation is attended with an increased activity of the nutritive processes, provided the supply of nutriment be sufficient, and provided also, that the exercise be succeeded by proper periods of rest. It is in this way only that we can comprehend the process of development of muscles by training; the conditions in training being exercise, rest following the exercise, and appropriate alimentation, the food furnishing nitrogenized matters to supply the waste of the nitrogenized parts of the tissues. This theory involves the idea that muscular work consumes a certain part of the muscular substance, which is repaired by food. The theory that the muscles simply transform the elements of food into force directly, these elements not becoming at any time a part of the muscular substance, is not in accordance with the facts known with regard to training.

"VII. All that is known with regard to the nutrition and disassimilation of muscles during ordinary or extraordinary work teaches that such work is always attended with destruction of muscular substance, which may not be completely repaired by food, according to the amount of work performed and the quantity and kind of alimentation.

"VIII. In my experiments upon a man walking three hundred and seventeen and one-half miles in five consecutive days, who at the beginning of the five days had no superfluous fat, the loss of weight was actually 3.45 pounds, while the total amount of nitrogen discharged from the body in excess of the nitrogen of food taken for these five days, assuming that three parts of nitrogen represent one hundred parts of muscular substance, as has been shown by analysis to be the fact, represented 3.087 pounds of muscular substance. This close correspondence between the actual loss of weight and the loss that should have occurred, as deduced from a calculation of the nitrogen discharged in excess of the nitrogen of food, seems to show very clearly that, during these five days of excessive muscular work, a certain amount of muscular substance was consumed which had not been repaired, and that this loss could be calculated with reasonable accuracy from the excess of nitrogen excreted.

"IX. Finally, experiments upon the human subject show that the direct source of muscular power is to be looked for in the muscular system itself. The

exercise of muscular power immediately involves the destruction of a certain amount of muscular substance, of which the nitrogen excreted is a measure. Indirectly, nitrogenized food is a source of power, as, by its assimilation by the muscular tissue, it repairs the waste and develops the capacity for work; but food is not directly converted into force in the living body, nor is it a source of muscular power, except that it maintains the muscular system in a proper condition for work. In ordinary daily muscular work, which may be continued indefinitely, except as it is restricted by the conditions of nutrition and the limits of age, the loss of muscular substance produced by work is balanced by the assimilation of alimentary matters. A condition of the existence of the muscular tissue, however, is that it cannot be absolutely stationary, and that disassimilation must go on to a certain extent, even if no work be done. This loss must be repaired by food to maintain life. A similar condition of existence applies to every highly-organized part of the body and marks a broad distinction between a living organism and an artificially constructed machine, which latter can exert no motive power of itself, and can develop no force that is not supplied artificially by the consumption of fuel or otherwise."

Prof. Flint, in an appendix, has added a calculation of the non-nitrogenized food taken by Weston during his five days' walk, in order "to answer the possible objections of those who may contend that, in his discussion, he should have included the heat-producing and force-producing power of non-nitrogenized alimentary substances." This calculation is briefly as follows:

Force-value of nitrogenized food	2,858.79	foot-tons.
" " loss of weight of the body	1,764.52	" "
" " non-nitrogenized food, in excess of that required to produce 17,787 heat-units (the amount of animal heat) produced in five days	597.75	" "
Total	5,221.06	" "
Deduct the estimated force used in circulation and respiration	1,339.29	" "
Force remaining for muscular work	3,881.77	" "

"The actual work represented by walking three hundred and seventeen and one-half miles is estimated at 4,321.33 foot-tons. This leaves 439.56 foot-tons of work which cannot be accounted for in any way, according to the estimates of the observers quoted, leaving a deficiency of a little more than ten per cent.

"These calculations show the fallacy of such estimates, and the impossibility of accounting for work actually performed, even when we include the heat-value and the force-value of non-nitrogenized food."

The estimates of the force used in circulation and respiration, and of the heat produced by the body, were all calculated for a condition of rest, and they are much less than the estimates that should be made for a period of excessive muscular exercise.

LIVING CORALS.

By W. E. DAMON.

PERHAPS enough already has been written about corals and coral-builders, but certainly too little is really *known* about the habits and mode of growth of this interesting animal. I am fortunate enough to possess fine specimens of some three or four varieties of living, working coral "polyps," for such is the name by which the coral-builder is designated. These specimens are kept in pure sea-water, and I have studied their habits very carefully for years; they seem to be in perfect health, full of activity, and generally industrious, although I can hardly observe that they have added to their corallum during this period. A specimen of *Astrangia* which has been described by Dana and Elizabeth Agassiz, although it has not, perhaps, increased visibly in height, has enlarged in size by building from its outer edges, and numbers of young and smaller polyps have appeared. I have noticed that this budding and increase occur about October or November of each year.

Nothing can be more beautiful than a group of these corallets. Sometimes a mass of them of three or four inches across is dredged up at Wood's Hole, Massachusetts. The polyps rise high above the cells, and, with their long, slender, fleecy, silk-like tentacles swaying to and fro, remind one of a living bed of roses, or of a mossy bank covered with heavy frost.

I have seen the animal of a single corallet standing above the surface of its cell an inch in height and expanded to one-third of an inch in diameter, and yet many—I may safely say, most people—believe the "coral-insect" (not an insect at all) to be a microscopic or a very minute animal. Its long, snowy tentacles are covered all over with warts or dots, with a larger one at the tip of each. All these contain its weapons of defense, called lasso-cells, or capsule-threads, with which the animal captures its prey. The smaller crustacea, coming in contact with these nettle-like arrows, are surely and suddenly disabled, and then with the longer tentacles are drawn inward to the mouth, which is situated in the centre of all these arms. This food passes into the stomach, which can be plainly seen through its glass-like walls, and must be digested before the animal retreats into its calicle. I have given them pieces of clams or oysters as large as half a pea, which they would seize with their tentacles and readily swallow. Another reason for this particular variety of coral-builder being so interesting to us is, that it is the only true coral-building polyp we have north of the Florida reefs, or nearer our homes than the Bermuda Islands.

Another variety, which belongs to the *Oculina* tribe, I have in

the same healthful condition. This one assumes a branched or tree-like form, and is, if possible, more elegant and beautiful than the last. Its zoöthome, when fully expanded, seems to completely hide the whole corallum, and nothing is visible but one mass or tree of *living, moving flowers.*

This polyp does not elongate itself so much as does *Astrangia*, and its tentacles are much shorter; and, instead of being white, it is of an umber-like color, and covered all over with iridescent hues. Its septa, or radiated plates of the corallum, are the same as in *Astrangia.* The common mass of coral is of a more solid, stone-like nature; the epitheca, or outer coral layer, which the *Astrangia* has not, and the endotheca, or coral inside the cells, are also more compact and hard.

POISONS OF THE INTELLIGENCE.—CHLOROFORM.[1]

By CHARLES RICHET.

CHLOROFORM is a colorless, volatile, oily liquid; it is denser than water, and does not mix with it. It was discovered by Soubeiran in 1831,[2] and Soubeiran's process for obtaining it is still in use, viz., distilling alcohol with calcium hypochlorite and lime. The hypnotic properties of chloroform were discovered in 1847 by Flourens, a few months after Jackson had recognized similar properties in ether; but the first surgeon who made use of it in an operation on the human subject was Simpson, of Edinburgh, in November, 1847. Since then, the use of chloroform has become so general, that nowadays no great operation in surgery is attempted without employing it. We may, therefore, justly regard the discovery of surgical anæsthesia as one of the greatest scientific achievements of the present century, so fruitful of benefits to the human race.

The principal effect of chloroform is the paralysis of sensibility, or anæsthesia. In so far forth it acts upon the mind, for sensibility is only one of the forms of mind; but this point, which as yet is rather obscure, calls for a few words of explanation.

Two great functions devolve upon the nervous system, sensibility and motion: it is through sensibility that we receive impressions from without; and it is through the excitation of the muscles, or movement, that we manifest our will, or act upon external objects. In the absence of both disease and poisoning, the will—that is, the

[1] Translated from the *Revue des Deux Mondes*, by J. Fitzgerald, A. M.

[2] The first discoverer of chloroform—for it was discovered independently by at least three chemists—was Samuel Guthrie, of Sackett's Harbor, New York. His discovery antedates Soubeiran's several months. Liebig's discovery of chloroform was intermediate between Guthrie's and Soubeiran's.—Translator.

mind—excites, through the spinal cord, the various muscles, producing movement; but this condition is not absolutely necessary, since in decapitated animals, for instance, the nervous system of the spinal cord can of itself produce motion of the muscles. Here we have motor activity, but no sensibility. Sensibility exists only where the mind is intact and capable of perceiving, so that a creature which has no mind is void of sensibility. This fact is confirmed by pathological observation; for, whenever the mind is affected, there appear at the same time symptoms of disordered sensibility, and *vice versa*. And when we find a patient exhibiting notable disorder of the sensibility, then, if the nerves are intact, we can safely conclude that the central nervous system is affected, and to that degree that the mind has not escaped.

Anatomy and physiology here are in accord with pathology. Some animals possess little or no sensibility: they belong to the lower grades of animals; their intelligence is obscure, and their sensibility is as obtuse as their intelligence. On the other hand, if we consider animals of higher intelligence, we find their sensibility becoming more and more keen, till we come to man, at once the most intelligent and the most sensitive of animals. And even in man himself we find race-differences, those races being most sensitive which possess the highest degree of intelligence. The anatomical structure of the nervous centres is in harmony with this coincidence, for it is in man that the posterior columns of the spinal cord are most voluminous, as compared with the anterior. Now, the anterior columns transmit the motor excitations to the nerves, while the posterior columns transmit the sensory excitations. Again, the posterior lobes of the brain in man, as compared with animals, are more developed than the anterior. But it is in the posterior lobes that perception of sensitive excitations appears to reside.

Nor is it surprising that there should exist so intimate a relation between mind and sensibility. Indeed, whatever may be the influence of the spontaneous development of the mind itself, resulting from the constitution of the brain, which is its organ, it still holds true that all our knowledge comes from our sensations, and from the brain-work thence resulting. Mind is, so to speak, the product of these two factors; and our notions of the world around us, elaborated and fecundated by the mind's spontaneous action, constitute individual personality. Hence, inasmuch as anatomy, physiology, and pathology, show intimate relation between sensibility and intelligence, we can justly say that psychology confirms the positive data furnished by these three sciences.

Accordingly, poisons which affect the intelligence are *ipso facto* poisons of the sensibility. In this respect alcohol does not differ from chloroform. When alcoholic intoxication is only beginning, we find already a notable degree of insensibility; but at the comatose stage

the insensibility is total, just as in the last stage of chloroform. Thus intoxication by chloroform and intoxication by alcohol proceed along parallel lines, and we can distinguish a first period of intoxication, properly so called, and a second period of sleep or coma.

When a person takes chloroform, the first few inhalations make him dizzy; he is seized with a sort of vertigo and dimness of vision. This vertigo goes on increasing, and, as the patient continues to respire the toxic agent, his ideas become more and more exalted. He hears what is said to him and makes replies, but he does so after the manner of a drunken man, at first exaggerating his impressions and regardless of proportion. His judgment has already disappeared, and he utters the most insignificant replies with a theatrical accent, the effect being often grotesque. Next, his ideas grow more and more mixed: will and judgment being gone, ideation is disordered and delirious; in short, we have a state of sleep accompanied with dreaming, closely resembling ordinary sleep.

When the chloroform absorbed by the mucous membrane of the lungs has passed into the blood, *active* memory, which presupposes attention and will, has disappeared; still, the intelligence is not yet dead. Ideas are still conceived, old recollections persist, and sometimes even the memory of past events is strangely quickened. The patient will speak in a language he thought he had forgotten, and recall old stories that seemed to have passed into oblivion. This superexcitation of memory is all the more interesting because in sundry forms of mental alienation it occurs with the same characters—these, too, being accompanied by entire loss of *active* memory.

Though insensibility supervenes very soon after the administration of chloroform, commonly it occurs only after the loss of memory, and this circumstance leads to very singular results. Thus, if the surgeon begins the operation before perfect insensibility has been produced, the patient will cry out, and beg to have it delayed till the drug has had full influence. One might suppose, from his cries of pain and his contortions, that the chloroform had produced no effect, and yet on awaking he has no recollection of what has taken place.

Is that real pain which leaves in the mind no trace? The answer to this question is not so easy as one might imagine. Suppose an acute, penetrating pain, continuing only for about one minute. Undoubtedly the patient suffers real pain during that minute; but, if all memory of it disappeared at once, then the patient would deny that he had suffered at all, and would not hesitate to undergo the operation again. In short, he would have enjoyed the benefits of chloroformic anæsthesia.

In administering chloroform, we must take account of the patient's temperament. If he is a resolute, courageous person, all will go on well, and the insensibility will readily disappear; if, on the contrary, he has an unconquerable dread of the operation, great watchfulness

will be necessary, for in such cases syncope is very frequent. Besides, such a patient resists the action of the drug for a long time, and it must be administered in far greater quantity than in the other case. The chloroform always retains its power, but the cerebral excitation to which some patients are subject enables them to resist its toxic action, as though the will could, so to speak, brace itself up to resist the action of the poison on the nerve-centres. The same occurs in the use of alcohol. One who *will* not be intoxicated may drink a large quantity without being drunk. At length, however, his will is conquered, and he falls to the ground, but he will not have experienced the exhilaration, the mad excitation, of the man who gives himself up to the influence of the liquor.

Thus, then, under the action of chloroform we find an antagonism existing between the various intellectual faculties—on the one hand the voluntary, and on the other the unconscious faculties. The latter are slowest to disappear; ideation, its guide and check, being deranged or destroyed, follows its habitual laws: association of ideas persists. External sensations are still borne in upon the mind, each one awaking a long series of ideas. As the sense of hearing is the last to disappear, the patient, though he can no longer either see or feel, hears every word that is spoken, and is set a-thinking at once. The same thing occurs in ordinary sleep, rarely in adults, but very frequently in young children. In fact, a certain degree of natural somnambulism is nearly always to be found in children. The child speaks out aloud without waking, he laughs and talks; more frequently he is frightened and cries. The course of his thoughts may be altered, diverted into another channel, by speaking to him gently, and this without arousing him from sleep. On awaking, all recollection of this has vanished. This method has been tried in mental alienation, to divert the thoughts of melancholics and hypochondriacs.

But soon these external phenomena which indicate the preservation of the intelligence, if not its integrity, disappear in their turn. The period of excitation is succeeded by the period of relaxation, and then the patient is in a deep sleep. However violent the external excitations, however painful the surgical operation, nothing can arouse the patient out of the comatose state into which he has fallen. His respiration is regular, his pulse slow and full, his pupils are motionless, and his features, paralyzed as it were, no longer wear that convulsive grimace which may be regarded as the last trace of sensibility. Intelligence is now destroyed. The coma of chloroform and that of alcohol appear to be essentially one. And, yet, what a difference! The former saves man from pain, the latter drags man down to the lowest depths of degradation; yet in both all signs of intellectual life have disappeared—there is a temporary death of the mind. It may be that, in the inmost nerve-tissues, brain-work still goes on, unconscious and silent, but whether this is so we know not.

SKETCH OF PROFESSOR SECCHI.

THIS distinguished Italian physicist and astronomer died on the 26th of February. PIETRO ANGELO SECCHI was born in Reggio, in Emilia, July 29, 1818. He was educated for the Church, and joined the order of the Jesuits November 3, 1833. He studied mathematics, physics, and astronomy, under Padre de Vico, and taught physics in the college of Loreto from 1841 to 1843. In 1844 he began his course of theology in the Roman College, and in 1848 came to the United States, and pursued his theological studies, at the same time teaching physics and mathematics, in the Georgetown College, District of Columbia. There he remained until 1850, when he was recalled to Rome.

He now entered upon his public career as an astronomer and physicist. He was appointed Director of the Observatory of the Roman College, reconstructed it on a new site and plan, invented and perfected an improved system of meteorological observation, published a monthly bulletin, which was continued until 1873, and invented and constructed a meteorograph, which was much admired by *savants* at the Paris Exhibition of 1867.

Prof. Secchi was commissioned by Pope Pius IX. to complete the trigonometrical survey of the Papal States, begun by Boscovitch in 1851, and to rectify the measurements already made of the meridional arc. He also superintended and executed successfully a commission to bring a supply of water to Rome from Frosinone, forty-eight miles distant. After the closing of the Roman College, and the expulsion of the Jesuits (1870–'73), Prof. Secchi was allowed to retain his post, and continued to lecture on astronomy in the ecclesiastical schools at Rome. In 1875 he was sent by the Italian Government on a scientific mission to Sicily.

Prof. Secchi was a man of great industry, and cultivated the astronomical field assiduously. The results of his scientific labors will be found chronicled in the periodicals of Italy, France, Germany, and England, and the "Smithsonian Contributions to Knowledge" in this country. But he is especially known in the scientific world for his researches and discoveries in spectroscopic analysis, and in solar and stellar physics. Among the most important of these are his "Spectrum Observations on the Rotation of the Sun," published in 1870. The same year he printed a large work on the sun, which was highly regarded, and immediately translated into French and German. His last considerable publication is a popular book on "The Stars," contributed to the Italian branch of the "International Scientific Series."

CORRESPONDENCE.

THE GERM THEORY.

To the Editor of the Popular Science Monthly.

IN your February number, Dr. J. R. Black assumes to correct Dr. Niemeyer's statement that the night-air of large cities is less noxious than the stirred-up air of the daytime, and he does so with a degree of confidence that seems to imply that there can be no such thing as doubting that he speaks *ex cathedra*.

Now, Dr. Black evidently believes that the insalubrity of city air depends upon the amount of non-respirable gases that may be diffused into the respirable ones; and is wholly independent of the condensible effluvia of the vaporous kind, or of the organic germ-dust that the heat and stir of the day may keep suspended, but would settle with the cooling and quiet of the night.

Now, while the precise application of the law to cities has not been made before, perhaps, in your journal, the teaching which inevitably leads to it has been abundant, and from unquestionable authority, so that, if Dr. Black wishes to correct so fatal an error as he charges this to be, he is very late with his solicitude. One lecture of Tyndall's, published by you, devoted much detail to the experiments of the professor, in his attempts to bottle a sterilized infusion in the laboratory of the Royal Institution, in air he had attempted to sterilize there, and explaining that he did succeed in a special chamber elsewhere. If, as Dr. Black would imply, noxious effluvia obey the law of diffusion of permanent gases, how comes it that they specially hover over low marshes and putrefying cesspools, while the ascent of a mountain of considerable elevation carries us above malaria and aërial infection, and often above bacterial decay?

A recent experiment of Tyndall's was to sterilize a bottle of infusion and open it upon the brink of a precipice, and, after contact with the air, recork it, to observe whether the infusion retained its sterility or not. He found the air germless. The experiment was made to test this identical question of the settling of ferment-germs.

Pasteur tried similar experiments, ascending to high points in Paris, bottling and comparing the air so bottled in putrefactive power with air bottled upon Mont Blanc, and with the air of the streets of Paris, always with the result of finding the air of the street levels more laden with micronymes than that obtained at considerable elevations. Upon the Western Plains, before civilization had scattered its filth, laden with zymogens, meats hung up in the air, even in midsummer, would keep sweet for days. The emigrants of 1849, in crossing the Plains, were surprised to find often the carcasses of dead animals of a previous caravan, drying-up viscera, and all without decay. This is easily explained on the germ-theory; without, it is inexplicable. If Dr. Black has any evidence that the germ-theory of decay and zymotic diseases is untenable, he should presently submit it, for, to my thinking, the world is only waiting to hear from Dr. Charlton Bastian, when the testimony and argument will be declared closed.

Respectfully,

C. W. JOHNSON.

ATCHISON, KANSAS, *February* 20, 1878.

THE HORSE IN AMERICA.

WE extract the following from a private letter of a Swiss archæologist:

"IN THE POPULAR SCIENCE MONTHLY of last November, page 121, I read that in Colorado on ruins more than 500 years old, probably much older, there are found drawings of horses. Can this be correct? I know there are found fossil remains of horses in America, but I know also that the horse was totally extinct in America at the time of its discovery by the Spaniards. Ruins on which drawings of horses are found must, therefore, be more recent than the discovery of America by the Spaniards. The well-preserved cedar-wood indicates that the ruins cannot be as old as the fossil horse. From the fact that no signs of a door are visible in the outer walls, and the ingress was from the top, I conclude that these ruins must have been built by the Pueblo Indians, or an allied race. I believe the Pueblo Indians to be the last remains of a more highly-civilized race, perhaps identical with the mound-builders, and would attribute to the same race the antiquities of Arizona. They have been almost exterminated by the later invasions of very distinct tribes. The aborigines of America did not know in 1492 the use of iron. That a skeleton in a Utah mound (page 123, ibid.) would have been found with a huge iron weapon in the right hand is therefore, for me, quite incredible. Also the occurrence of wheat in the same mound and of bones of *sheep* in the Colorado ruins. Except

the llamas and alpacas of Peru, the aborigines of America in the fifteenth century had no cattle whatever, and the domestic sheep and the wheat have been introduced by the Europeans in America.

"Was the skeleton in the Utah mound of the Indian red race? Then it must be more recent than the European invasion which brought wheat and cattle to America. Or is it possible that the Colorado ruins and the Utah mounds relate to an Asiatic invasion which brought iron, wheat, horses, and sheep, into America before the European invasion, but was exterminated, with its wheat and cattle, by the Indians long before Columbus. Elephants' heads, represented on the walls of Palenque and other Mexican ruins, would support a similar view, if they do not belong to extinct species, which would prove an enormous age for these ruins. However this may be, it cannot be doubted that in 1492 the natives of America knew neither elephants, nor horses, nor sheep, nor wheat."

EDITOR'S TABLE.

AMERICAN CONTRIBUTIONS TO ELECTRICAL SCIENCE.

THE story of electricity forms the most romantic chapter in the history of science. The curious thing about it is, that it has been a progress from utter and absolute ignorance to the most familiar and extensive practical results. In all the other sciences—mechanics, optics, physiology, astronomy—there was a basis of common knowledge, consisting of many familiar facts to start with, and there is ever a rudiment of science in the loose observations of uninstructed people concerning things that fall within the range of ordinary experience. But electrical science had no such starting-point—nothing was known by common people of any such agent. Lightning was hardly regarded as a terrestrial thing. It was the bolt of Jove, a minister of God's wrath, or a malign agency of the prince of the powers of the air, a kind of preternatural phenomenon; and, when amber was rubbed and found to attract light bodies in a mysterious way, it was assumed to have a soul and to be a sacred thing. This little seed of the science did not germinate for thousands of years. It was an instructive test of the culture of the human mind, and shows what an enormous amount of preliminary mental activity had to be expended before men were prepared to engage in the study of Nature. The natural world was filled with this force which we now call electrical; all things were pervaded by it, but it was beneath the surface; it did not strike the senses, and compel attention; it could be discovered only by thought, and the investigation could not commence until the human intellect had been turned in a systematic way upon natural things. But when experimental inquiries in electricity were once begun, their results were so curious and peculiar that they exerted a powerful fascination over the wonder-loving, and by this stimulus the science grew rapidly. It has given rise to a brilliant series of electrical and magnetic discoveries, inventions, and useful applications, of the widest range and the highest utility to civilization, such as no other science has afforded. The intellectual movement has here been from the zero of total ignorance, through long observation and experiment, up to the richest harvest of wonderful works.

It is interesting to note how fully this science belongs in its development to civilization, and how widely its discoveries are to be apportioned among different nations, and it is not to be overlooked that the New World shares these honors conspicuously with the Old. The Englishmen Gilbert and Gray were prominent in laying its foundations; the German Guericke contributed essentially to the work, and Du Fay, the Frenchman, gave ear-

ly form to its theoretic structure. The next, and by far the most brilliant step yet taken, was made by the American Franklin in demonstrating the identity of lightning and common electricity, and in the invention of the lightning-rod. The Italians Galvani and Volta then followed, giving us the electrical batteries that bear their names; the Englishman Davy soon made an epoch in electro-chemistry; and Oersted, the Dane, came next with the discovery of electro-magnetism. This paved the way for the era of the successful establishment of the telegraph; and here our countryman Morse was a leader, whose name is everywhere indissolubly linked with the system.

All these achievements in the progress of the science were regarded with incredulous astonishment when they were made; but the recent exploits in the field of electrical invention and discovery surpass, if possible, in their wonderful results, all that has gone before, and here the work is exclusively American. The musical telephone of Elisha Gray, and the speaking telephone of Graham Bell, together with the Phonograph of Thomas Edison (which, although not an electrical machine, grew out of the telephone), were all invented in this country, and they nobly "crown the first two years of our new century." The import of these devices is being increasingly appreciated by scientific men as their powers are developed, and eminent foreign electricians have pronounced them the most extraordinary productions of the present century. Experimenters abroad may be expected to contribute to the elucidation of their conditions and principles, but they will do well not to overlook what has been accomplished here. Already, they are taking credit for contrivances which are but repetitions of American work. Dr. William F. Channing, of Providence, who, with other gentlemen of that city, have taken an active interest in the telephone from the outset, and contributed valuable aid to Prof. Bell in perfecting his invention, thus writes to the *Journal of the Telegraph* in reference to things done on the other side, that had been anticipated here:

"A considerable flourish has recently been made over the multiple telephone of M. Trouvé in Paris. As the speaking telephone is entirely an American discovery, it is worth while to keep the credit of what we do at home.

"The multiple telephone, that is, a cubical or polyhedral chamber, every side of which, except the front, is occupied by telephone-plates with magnets, etc., behind, was made last summer, by Henry W. Vaughan in Providence, before the speaking telephone had been seen in France.

"In a recent lecture upon the telephone before the Franklin Society of Providence, I had the pleasure of using a pair of sympathetic or rather responsive tuning-forks, made many months ago by Prof. E. W. Blake, of Brown University. These tuning-forks were of the same musical pitch, and each mounted on a sounding-board. They were also tempered and magnetized, so as really to constitute permanent U magnets. Between the poles or ends of the prongs of each of these magnetic tuning-forks, a short soft-iron core, surrounded with a coil of fine insulated wire, was supported, very near, but not in contact with, the prongs of the tuning-fork. These instruments were placed in a common telegraphic circuit a sixth of a mile apart. When the distant instrument was struck, the other responded so as to be heard throughout the lecture-room. This is a form of the responsive tuning-fork, much more beautiful than that figured in *Nature*, and ascribed to W. C. Röntgen; and it anticipated European application by several months."

MR. WALLACE AND CLAIRVOYANCE.

We have followed up the controversy that grew out of the publication of Dr. Carpenter's lectures on spiritualism, and, having printed in the Monthly an adverse review of that book by a leading representative of the spiritualist party in this country, we have republished in successive numbers of the Supplement the replies to Dr. Carpenter

made by those eminent scientists, Mr. William Crookes and Mr. A. R. Wallace. We supposed, from intimations in this last and shorter installment, that the discussion was ended; but Mr. Wallace comes on again in the last *Athenæum*, and, as the logomachy may prove interminable, *we*, at all events, shall have to stop. Nothing would be gained by printing Mr. Wallace's last letter in full, but some notice of his positions may be desirable.

The relation of official French inquiry into mesmerism, animal magnetism, and clairvoyance, has been a prominent question in this controversy. The main facts seem to be these: In 1784 the French Government ordered the medical faculty of Paris to investigate the theories of Mesmer, who had been making a great stir in that city, and report upon them. A committee was appointed, of which Franklin and Lavoisier were members, and their report was adverse to the validity of Mesmer's claims. In 1825 the believers in animal magnetism applied for a new commission, which was appointed by the Academy of Sciences, and consisted of five members, who made a favorable report upon the subject in 1831; but this report was neither adopted by the Academy nor regularly printed in its memoirs. In 1837 the French Academy appointed a new commission of nine members, who reported adversely upon the doctrine of animal magnetism, and their report was adopted by the Academy; and still another commission was afterward ordered by the same body, and with the same result. Mr. Wallace complains that Dr. Carpenter, in his historical sketch of the subject, ignored the report of 1831, which was on the side of mesmerism, and was not accepted by the French Academy, and he devotes his last letter to a statement of the points made in that report. Mr. Wallace assures us that the commission "obtained absolutely conclusive facts, which have subsequently been often confirmed, but have never been satisfactorily explained away." Among these is the proof of clairvoyance. The committee say that "prevision of organic phenomena, knowledge of the internal conditions of other persons, and true clairvoyance, had been demonstrated to them." Mr. Wallace adds: "One of the somnambulists determined correctly the symptoms of M. Marc, a commissioner; and also the disease of another person, the accuracy of the diagnosis being confirmed by *post-mortem* examination. Clairvoyance was proved by one of the patients repeatedly reading and naming cards while four of the commissioners successively held his eyes closed with their fingers—a test, the absolute conclusiveness of which each one may satisfy himself of."

The term *clairvoyance* means literally clear sight. But everybody with good eyes has clear sight; the alleged vision is, therefore, not of the ordinary kind. It claims to be an extraordinary kind of seeing, a seeing through opaque objects—through the eyelids, through bandages, or through the back of the head, and into objects not penetrable by ordinary vision. The term "clear," as applied to this kind of sight, is intended to denote especial or remarkable clearness, or a transcendental vision, which opens to sight things not sensible to the normal eye. In short, clairvoyance affirms an extra endowment for making things visible which goes beyond the range of that sense which is our usual source of knowledge.

Now, Mr. Wallace says that this is an "absolute fact," which has been conclusively proved and known for forty-seven years, or since the report of 1831, that declared it to be demonstrated. As, therefore, this remarkable endowment of human nature has been established as a fact for nearly half a century, we are fairly entitled to ask, What have been its results? If it be true, no discovery ever made in science can for a moment bear comparison with it in importance; and if it be true, we have a

right to demand the legitimate results that must flow from it, as we expect and require the natural results of all other genuine discoveries. Of course, the objection may be interposed that we must not be premature in anticipating the fruits of discovery, because the history of all science shows that the interval between the dawn of a new principle and its developments and applications may be very long. This is true; yet, in every case, we demand at once the effects that flow immediately from the quality of the discovery; in fact, we only know it by these results. It would, of course, have been absurd to expect from the invention of the spy-glass the great results of the modern telescope, which has grown out of it; but it would have been proper to expect from the spy-glass that which was properly claimed for it, and which it at once compelled all men to yield. All scientific discoveries, in fact, are new procurable effects, and are, therefore, their own witnesses. Clairvoyance *must* give us the new results of a marvelously-sharpened vision; the extra faculty implies extra disclosures. And again we ask, where are they? With a new capacity for seeing, what new thing has been seen? The limitations of vision restrict and measure the usual sphere of knowledge, and with every increase in the power of optical instruments, as the microscope and telescope, in aiding the eye, knowledge has been extended, novel facts brought to light, and it is these that attest the instrumental improvements. But with a power of vision so mysteriously sharpened that opaque objects become transparent, with the barriers actually taken away, what has been revealed? There are thousands of perplexing and unsettled questions, regarding the constitution of material things, which might be cleared up by another increment of visual penetration; but clairvoyance has given no help in conquering these difficulties. If it has been a demonstrated reality these fifty years, it ought long ago to have vindicated its claims by unveiling some of the obscurities of material objects. Yet, claiming to be a superior means of laying open the inner constitution of things, it has not even proved equal to ordinary sight, and has, in fact, done nothing whatever toward extending the boundaries of knowledge. It may, perhaps, be objected that clairvoyant power of seeing through opaque things no more implies a revealing of their inner nature, than looking through the air with the eye implies the recognition of its physical and chemical constitution. But this plea for seeing nothing, with a preternatural gift of sight, is futile, and the advocates of clairvoyance understand well enough that the validity of the claim must turn on what is recognized; accordingly, the French commissioners say it had been demonstrated to them that clairvoyance gave a knowledge of the internal condition of other persons. The body was not looked through as we look through the air, where nothing is seen; but it is claimed that things were seen, internal conditions perceived, morbid actions identified, and features of disease described, that were confirmed by *post-mortem* examination. Why, then, should this power be confined to the identification of things already ascertained by the common resources of inquiry? The new way of getting into the mysteries of the organism should have attested itself by results not accessible by ordinary means. It is significant that the clairvoyant reports only as far as normal knowing had already reached. Yet the human system is filled with physiological and pathological enigmas and obscurities, the clearing up of which would be priceless to science. Why, then, did not the physicians of the French commission close the investigation at once and forever by throwing light upon organic processes not before understood, and thus vindicating the new method, by showing that it could do, in a direct way, at least as much as

we are now able to do indirectly, though only by long and difficult processes of investigation?

This is certainly a dictate of common-sense. The test of clairvoyance is what the alleged exceptional clearness shows. The question is, Can the clairvoyant actually do what he pretends to do? And the proof is not the mere testimony of a few parties, who say they have seen extraordinary things, but what has been positively, and demonstrably, and openly gained to science? This is the test in the case of all other scientific discoveries. M. Burdin, a member of the Academy of Sciences, put the claims of clairvoyance to very simple and decisive proof in 1837, when the real "evidence" signally failed. He placed 3,000 francs in the hands of a notary, subject to the order of the Academy, to be given to any one who would read writing placed in an opaque box, a committee of the Academy being appointed to supervise the experiments. The conditions were modified in various ways to suit objectors, the only point being to determine whether the clairvoyant could actually see through an opaque substance, and the time allowed to find a party who could do this, at first two years, was extended to three. Numerous trials were made, but none succeeded. The result, however, of the carefully-conducted experiments was to detect, in several instances, the fraudulent mode in which the alleged previous successes had been obtained.

NEW SOLAR PHOTOGRAPHS.

M. Janssen, the eminent director of the observatory at Meudon (France), has for some time been giving his attention to solar photography, and with singular success. The very remarkable photographs he has lately produced have hardly yet reached this country; but, from the examination of one, sent by him to the Allegheny Observatory, and which we have had the opportunity of seeing, we find that the praise bestowed abroad upon these new results is fully deserved.

The surface of the sun itself has been described by recent observers as consisting of a relatively *dark* background, thickly starred in every part by those strange objects called technically "granules," or "rice-grains," and which constitute the real source of the solar light. These, which have hitherto only occasionally been seen by good telescopes, are now definitely fixed for us by the camera, and we may see for ourselves that they, with their surrounding gray, do resemble—to compare great things with small—rice in a plate of soup, though the photograph shows that they are not in general elongated, but nearly round, with an irregular outline, as described by careful observers. We must leave, however, to special students the study of these details, and only observe that the photograph, besides confirming previous optical observations as to the remarkable fact that the light and heat of the sun come from but a small part of its surface, adds otherwise directly to our knowledge, by presenting new facts, such as the evidence of storms upon the solar surface (quite away from the spots), which have never yet been distinctly observed by the telescope.

These admirable photographs can hardly fail to soon become known, by copies to the scientific public, for they constitute a most essential step in the study of the sun, and one on which M. Janssen is certainly to be congratulated.

THE EDISON PHONOGRAPH.

In a certain sense, this "acoustical marvel of the century" is as simple as a grindstone; but, in a scientific point of view, there are subtile questions about it that only trained physicists can appreciate. Prof. Mayer's article upon the subject, in the foregoing pages, besides accurately explaining the mechan-

ism and its operation, points out the delicate complexity of its effects in a way that will interest all curious-minded readers. Mr. Edison, by this invention, has done for sound what Daguerre did for light—made it possible to fix and permanently retain the most fleeting impressions. We pointed out, last month, the marvelous capacities of cold iron, magnetism, and an electric wire; but the capacities of the phonograph are still more marvelous, for, with only a vibrating plate, a sheet of tin-foil, and a crank, it is possible to arrest and fix all kinds of sound, and, having preserved them as long as metals will hold their properties, to give them forth again in all their original qualities. The voice, indeed, is somewhat muffled and minified when returned from the iron tongue of the phonograph; but its intonations, inflections, pauses, and quality, are rendered with surprising fidelity. By the simple turning of the crank, the machine talks, sings, shouts, laughs, whistles, and coughs, so naturally and distinctly, that the listener can hardly believe his senses, or escape from the suspicion that there is some ventriloquist hocus-pocus about it, or a little fellow concealed somewhere about the arrangement. But the fact is established, and must be made the most of. A machine, as simple as a coffee-mill, hears a speech or a song, and gives it back as perfectly as it was at first uttered by the living organs of voice. And so, again, we have the lesson repeated, with still greater emphasis, that we must raise our estimate of the powers and potencies of "mere dead matter."

LITERARY NOTICES.

PHYSIOGRAPHY: An Introduction to the Study of Nature. By T. H. HUXLEY, F. R. S. With Illustrations and Colored Plates. Second edition. Pp. 377. New York: D. Appleton & Co. Price, $2.50.

THIS volume has been prepared as a school text-book on the subject hitherto known as physical geography, but in its method it is very different from the usual works upon that subject. Of course, Prof. Huxley could not enter upon this field without taking his own view of its method of treatment, and making an original book, but beyond this he has unquestionably made a very valuable contribution to educational literature. In the following passage from the preface he puts the subject upon its rational and proper basis. He says:

"I do not think that a description of the earth which commences by telling a child that it is an oblate spheroid moving round the sun in an elliptical orbit, and ends without giving him the slightest hint toward understanding the ordnance-map of his own county, or any suggestion as to the meaning of the phenomena offered by the brook which runs through his village, or the gravel-pit whence the roads are mended, is calculated either to interest or to instruct. And the attempt to convey scientific conceptions without the appeal to observation which can alone give such conceptions firmness and reality, appears to me to be in direct antagonism to the fundamental principles of scientific education."

Prof. Huxley was led to the preparation of this volume in consequence of having been invited, several years ago, to give a course of lectures before the London Institution, which were intended to initiate young people into the elements of physical science. Prof. Huxley took the opportunity thus afforded to put into practical shape ideas long entertained respecting the proper method of approaching the study of Nature. Twelve lectures were given, not on any particular branch of knowledge, but on natural phenomena in general, and the title "Physiography" was taken to distinguish both as to matter and method between the subject and what is commonly understood as physical geography. The ideas which Prof. Huxley aimed to embody in these lectures, and which characterize the present work, are thus happily presented by himself:

"It appeared to me to be plainly dictated by common-sense, that the teacher, who wishes to lead his pupil to form a clear mental picture of the order which pervades the multiform and endlessly-shifting phenomena of Nature, should commence with the familiar facts of the scholar's daily experience; and that, from the firm ground of such experience he should lead the beginner, step by step, to remoter objects and to the less readily comprehensible relations of things. In short, that the knowledge of the child should, of set purpose, be made to grow, in the same man-

ner as that of the human race has spontaneously grown.

"I conceived that a vast amount of knowledge respecting natural phenomena and their interdependence, and even some practical experience of scientific method, could be conveyed, with all the precision of statement which is what distinguishes science from common information; and yet, without overstepping the comprehension of learners who possessed no further share of preliminary educational discipline than that which falls to the lot of the boys and girls who pass through an ordinary primary school. And I thought that, if my plan could be properly carried out, it would not only yield results of value in themselves, but would facilitate the subsequent entrance of the learners into the portals of the special sciences."

Prof. Huxley fulfilled this idea with great approval in his lectures. He began by ideally placing his audience upon London Bridge to observe and consider the river-phenomena of the Thames. From this point, step by step, he worked over the field, constantly using illustrations and explaining effects that were familiar to his hearers. In this aspect, therefore, the book has a flavor of locality, but the thoughtful teacher in using it will simply transfer its applications to his own region. The book is beautifully illustrated, and should find its place, if not as a class-book, at least as a book for reading and reference, in every school.

LETTERS OF CHAUNCEY WRIGHT. WITH SOME ACCOUNT OF HIS LIFE. By JAMES BRADLEY THAYER. Privately printed. Pp. 383. Cambridge: Little, Brown & Co. Price, $2.50.

WE have found this volume very pleasant reading, as it delineates the features of a marked personality, and makes us acquainted with the somewhat peculiar life of a man who was thoroughly appreciated and much beloved by his friends. His printed letters are most readable, and, though not brilliant, they seem to us quite superior in simplicity and clearness of style to his more elaborate published essays; and this too when he is treating of the same subjects. He was born at Northampton, Massachusetts, in 1830, entered Harvard College in 1848, passed the rest of his life at Cambridge, and died suddenly, of apoplexy in 1875. He was employed in the office of the *Nautical Almanac*, took occasional private pupils, taught in Prof. Agassiz's school for young ladies, was an instructor in the college, and one of the university lecturers. His literary work consists of articles contributed to the *North American Review* and the *Nation*. The following passages from his biographer's description of his character will give the reader a good idea of some of its aspects:

"Calm, gentle, unassuming; ready to be pleased; demanding little of his friends; as pure as a woman in thought and speech; fond of children, and unwearied in giving them pleasure; free from passion to a defect; never selfish, though at times, from preoccupation of mind or from lack of imagination, not wholly considerate; deficient in ambition; devoid of jealousy and envy; perfectly honorable and perfectly amiable—these stand out in the memory of his oldest friends, as the last impressions of his character, the same large features, great simplicity and great dignity, which would have struck an observer meeting him for the first time. . . .

"His writings were more like simple transverse sections from a web that was ever unrolling itself from the loom of his busy brain than like pieces woven for the occasion, in which a particular effect was to be produced by proper combination of the material at his command. I fear that my illustration may not seem a very pertinent one; but it presents itself naturally to me as I recall the process of composition of the bulk of his published essays, and many more that never went beyond his friends. He wrote with pencil, usually in a note-book; and, when he was in the mood of composition, wrote pretty steadily all day and far into the night. He was too precise in thought and expression to need to correct much or to revise what he had written; and I can hardly recall an instance of his rewriting, or rather reshaping, an essay, short or long. The starting-point was usually some fruitful reflection that promised to reward development; and from this point he would proceed on what was really a voyage of discovery, though in waters that were in general familiar to him. What he wrote during the day would probably be read to me, or the friend that was nearest, the next day, and talked over in a way. The end often came quite as much because the *afflatus* had ceased as because a natural conclusion had been reached. What he thus produced were rather studies than finished work. They aided him to make his own thought clear to himself, but were little fitted to impress that thought upon others. Original, solid, suggestive, as they always were, from the very manner of their production they lacked proportion, relief, perspective. It seems a hard thing to say of our Chauncey, the most simple, modest, and unconscious of men, that he never knew how to sink himself in his subject; yet just here, in the lack of instinct to discern how the minds he was addressing would be affected, and in the lack of discipline to accommodate the workings of his own mind to their needs and not unreasonable demands, lies the explanation that an intelli-

gence so rich and powerful, so eager to give of its abundance, has not left the world more in his debt. He fell dead at the very noon of intellectual life, as he would have wished to do, at his desk; but, from the qualities of which I have spoken, I doubt whether he would ever have been appreciated properly as a thinker outside of a small circle of readers, had his life been prolonged ten or twenty years."

FREETHINKING AND PLAIN SPEAKING. By LESLIE STEPHEN. Pp. 362. New York: G. P. Putnam's Sons. Price, $2.50.

THIS is an able vindication of what surely needs to be vindicated—the duty of plain speaking. The peril of it is chiefly maintained by those who are skeptical at the core about things to which they give a public adhesion. There has been a great advance in the liberty of plain speaking, and almost a corresponding advance in the liberality with which it is received. And, with this increasing toleration of it, plain speaking has grown more civil, and no longer means, as too often it used, violent and ill-tempered assaults on decent and cherished, though antiquated, theories of life here and hereafter. This book is itself an excellent example of the lesson it inculcates. The first essay is entitled "The Broad Church." It examines the position of those who adopt the formularies of the Church as being the expression of their deepest conviction, who repeat the creeds, who subscribe to the Thirty-nine Articles as often as desired, but who at the same time express their desire to discover and follow the truth, and do actually hold rationalistic views. The various arguments by which this course is sustained are considered, and attention is given to the ingenious devices by which these gentlemen, who are given the fullest credit for honesty and sincerity, endeavor to reconcile the difficulties of their position. The conclusion is reached that the attitude is a perilous one, and that the efforts to maintain it are painful and humiliating. We have a good illustration of this in the recent discussion of eternal punishment.

In the excellent chapter on "Darwinism and Divinity" is shown, among other things, the utter fallacy of the notion that existing creeds are the sole bulwarks of morality. Of course, if it be admitted that God gave the Commandments directly to man; that he proclaimed from Sinai the existence of a heaven and a hell; and that these are the foundation, instead of the outgrowths, of our moral nature—then their overthrow might imperil morality. But this radical ground is seldom taken now, and, if it be conceded that beliefs are generated from within, the argument disappears. The virtuous instincts which have contributed the best which is in theology may safely be intrusted with the care of morality when theological dogmas have become obsolete.

The last essay, called "An Apology for Plain Speaking," is an appeal to those who agree with Mr. Stephen in his conclusions to state their agreement in plain terms, and meets the questions, "Why attack a system of beliefs which is crumbling away quite fast enough without your help?" "Why try to shake beliefs which, whether true or false, are infinitely consoling to the weaker brethren?" For the answer to these questions, we must refer the reader to the book itself, commending its closing passage: "Let us think freely and speak plainly, and we shall have the highest satisfaction man can enjoy—the consciousness that we have done what little lies in ourselves to do for the maintenance of the truths on which the moral improvement and the happiness of our race depend."

THE SOURCE OF MUSCULAR POWER. ARGUMENTS AND CONCLUSIONS DRAWN FROM OBSERVATIONS UPON THE HUMAN SUBJECT UNDER CONDITIONS OF REST AND OF MUSCULAR EXERCISE. By AUSTIN FLINT, Jr., M. D. Pp. 103. D. Appleton & Co. Price, $1.

DR. FLINT here attacks one of the most interesting questions in physiology—one which has attracted much recent attention, and given rise to earnest controversy. The issue discussed in this volume was first brought prominently forward and closely investigated by Prof. Liebig nearly forty years ago. It received a new impulse in 1866 by the researches of Professors Fick and Wislicenus, and the views put forth by these *savants* have been brought under critical scrutiny in later observations upon the expenditure of force by celebrated pedestrians. Prof. Flint had a hand in this work, and, after the publication of Dr. Pavy's experiments upon Perkins and Weston in

London, he reviews the whole subject for the purpose of determining how the question stands at present. The problem is so important that we print an article giving a compact presentation of his reasonings and conclusions; but those who desire to become familiar with the complete inquiry will find the volume indispensable.

THE KABALA: OR, THE TRUE SCIENCE OF LIGHT; an Introduction to the Philosophy and Theosophy of the Ancient Sages, together with a Chapter on Light in the Vegetable Kingdom. By S. PANCOAST, M. D. Pp. 304. Philadelphia: J. M. Stoddart & Co. Price $2.

THERE is an old mystical Jewish tradition in regard to occult meanings of Scripture which is called the Kabala. An amazing amount of learned ingenuity has been expended upon it, and many books written of kabalistic lore, designed to solve these enigmas, and bring out their mysterious meanings. It has been held, indeed, that the Kabala is nothing less than a profound science, which, if opened up, would explain numberless hidden things in regard to prophecy, Scriptural interpretation, theosophy, and the order of Nature itself.

Dr. Pancoast calls his book the Kabala, and says he has been working at it for thirty years, and has found the keys that open its mysteries; and he says, furthermore, that it is a great thing, and is all that has been claimed for it. Nor does he suppose that its benefits are to be confined merely to the explanations of old riddles, or the development of a fruitless philosophy; he holds its results to be of a very practical kind in influencing modern opinion. One of these important advantages is stated to be that "a just appreciation and knowledge of the Kabala would stop infidelity, that is defiantly stalking through the world, uprooting, tearing down, razing, actually burying faith in God and his salvation." So potent an instrumentality is certain to be well appreciated, but expectation is dampened when we are informed that this book is not designed to contain the presentation that will work such important effects. Dr. Pancoast proposes, therefore, to make another, saying, "We have in contemplation the publication of a large, full, candid exhibit of what the Kabala is, has done, is doing, and shall do for the world." If it is to be as efficacious in composing men's distracted beliefs as is here proclaimed, we say, let the doctor hurry up his big book with all dispatch.

But let nobody buy the present volume in the hope of getting any help from it in the direction indicated. It is in fact as remote as possible from any such end. It is nothing less than a kind of doctor's book on light, which the author proposes to substitute for pills. He is a collaborator in the curious field, cultivated with such brilliant but transitory results by General Pleasonton. He believes in the remedial efficacy of blue light, and prints his book in blue ink; but he goes further than General Pleasonton, and holds also to the therapeutic virtues of red light. He talks a great deal about the science of light, and his discourse is quite in the Pleasonton strain. That is, his science is his own, and is very much freed from the trammels and limitations of the common kind of science that goes current in the text-books. His view of the luminiferous agent is thus stated: "Light is the original source of Life. Motion is Life, and Light is the Universal Motor. There is no force in Nature that is not directly derived from Light; the Physical Forces, Attraction and Repulsion, with all their modifications, are the positive and negative principles of Light, acting in matter—they are the objective Forces of Light as they operate in creating and dissolving inorganic material forms." The author has given us a book full of such kabalistic conundrums in the science of optics.

WHAT WAS HE? OR, JESUS IN THE LIGHT OF THE NINETEENTH CENTURY. By WILLIAM DENTON. Pp. 259. Wellesley (near Boston): The Author. Price, $1.

THE "light of the nineteenth century," in which the author studies Jesus of Nazareth, is the "new light" of spiritism. In this light, supplemented with scintillations of "psychometry," Mr. Denton proves (to his own satisfaction) that Jesus was a "medium" of considerable power—a clairvoyant, and a natural healer. In the latter capacity, however, he was hardly the equal, in this author's opinion, of a certain notorious "magnetic physician" whom he names, and whose "testimonials from the people" he reproduces.

CONTRIBUTIONS TO NORTH AMERICAN ETHNOLOGY. Vol. I., pp. 361, with numerous Plates. Washington: Government Printing-Office.

FOR many years Prof. J. W. Powell, geologist in charge of the United States survey of the Rocky Mountain region, has made the languages of the Indian tribes an object of special study, the result being the collection of a large number of vocabularies. Having decided to prepare this material for publication, he invited the coöperation of the Smithsonian Institution, whose collections of similar materials are very extensive. Prof. Henry, secretary of the Institution, promptly consented to place in the hands of Prof. Powell all this material, consisting of several hundred MS. vocabularies, together with voluminous grammatical notes on the dialects of the Indians throughout the greater part of North America. This first volume of the "Contributions" is made up of two parts, the first, by William H. Dall, treating of the "Distribution, Population, Origin, and Condition, past and present, of the Native Races inhabiting our Extreme Northwestern Territory;" and the second by Dr. George Gibbs, on "The Indians of Western Washington and Northwestern Oregon."

A MANUAL OF HEATING AND VENTILATION. By F. SCHUMANN, C. E. Pp. 89. New York: Van Nostrand. Price, $1.50.

THE design of this manual is to furnish to the hand of the engineer and the architect, in such shape as to be fitted for practical application, the formulæ and data necessary for computing the dimensions and determining the other conditions of heating and ventilating appliances. A manual of this kind is simply indispensable to the professions for whose use the work was compiled.

A MANUAL OF INORGANIC CHEMISTRY. Vol. II. The Metals. By T. E. THORPE, Ph. D. Pp. 406. New York: Putnams. Price, $1.50.

THE properties and combinations of the metals are here fully and clearly described, the text being very efficiently supplemented by numerous well-executed wood engravings. The volume belongs to the excellent "Advanced Science Series," published simultaneously in Glasgow and New York.

THE *Bulletin of the Nuttall Ornithological Club* has been enlarged, the number of pages being now 48, whereas formerly it was only 24. It is gratifying to observe this sign of prosperity, and we have no doubt that the *Bulletin* is now on the high-road to assured success. It is eminently deserving of support from all lovers of the delightful branch of zoölogical science to which it is devoted. The *Bulletin* is edited by Mr. J. A. Allen, with the active assistance of Prof. S. F. Baird, and Dr. Elliott Coues, and the foremost ornithologists of the United States are frequent contributors either of set articles, or of brief notes of observation. For the scientific ornithologist, no less than the amateur, it is indispensable. Subscription, $2 a year. Address, Ruthven Deane, Cambridge, Mass.

THE SILVER COUNTRY, OR THE GREAT SOUTHWEST. By A. D. ANDERSON. Pp. 221, with Map. New York: Putnams. Price, $1.75.

THE "Great Southwest" of this author is the "New Spain" of the period of Spanish power in America. In successive chapters the author describes the physical and political geography of this region; its wealth in silver and gold; other wealth than the precious metals, i. e., its agricultural productions, luxuries, and attractions, with sections on such topics as facilities for acquiring wealth, scenery, and wonders, antiquities, etc.; foreign commerce of Mexico; advance of railways. Finally, there is a very full bibliographical chapter on the "authorities" whose works have been of service in collecting materials for the work.

A GUIDE TO THE DETERMINATION OF ROCKS. By EDWARD JANNETTAS. Translated from the French by GEORGE W. PLYMPTON, C. E., A. M. Pp. 161. New York: D. Van Nostrand, 1877. Price, $1.50.

THIS is a plain, brief, but comprehensive introduction to the study of the more common rocks, and of the minerals of which they are composed. The English synonyms for the rock-names are from Von Cotta's "Rocks classified."

Part III., giving the method to be followed in the practical determination of rocks, will be found of especial value to beginners.

A System of Volumetric Analysis. By Dr. Emil Fleischer. Translated from the German by Prof. Pattison Muir. Pp. 274. Macmillan & Co. Price, $2.50.

There are two methods of chemical analysis, when the operation is carried to its highest result for the purpose of establishing quantities in chemical composition. The first, and older method, is that by weighing; it involves the use of the balance, and is called the gravimetric method. The second, and newer mode, is by measurement of bulk; instead of the balance, it employs the burette, a graduated glass tube, and it is called the volumetric method. There are certain advantages in the newer process which are becoming more marked as it is more practised and developed. The superiority claimed is greater simplification and quickness of operation, with an equal and sometimes a greater degree of accuracy. Dr. Fleischer's treatise has been translated into English because it is a systematic work upon the subject, accepted as a standard in Germany, and believed to be much better for students than any original contribution to the subject in our own language. The present transitional state of chemical science, in regard to theories and the modes of expression that follow them, is well illustrated by the fact that the author of the book adopts the old notation, while his translator adopts the new. The consequence is, that both methods are given, which is a good feature of the work, and the translator thinks that the putting of the two notations, side by side, will be useful as disclosing the superiority of the newer plan.

Philosophic Ideas. By J. Wilmshurst. Pp. 151. Boston: Colby & Rich.

The precise nature of this author's "philosophic ideas" may be inferred from his highly-satisfactory explanation of Newton's law of gravitation. "Why," he asks, "does matter tend to approach other matter, and why should it approach with constantly accelerating speed?" And his answer is: "This action is the necessary outflow of the deific attributes essential to matter. Its love and intelligence are shown in approximating, so that it can mutually impart and receive more of each other's beautiful and pleasing varieties of motion by sympathetic action." And so on.

Tenth Annual Report of the Peabody Museum of American Archæology and Ethnology. Cambridge, 1877. Price, $1.

Besides the report of additions made to the museum and library in 1876, which were large and valuable, this volume contains reports of explorations in American archæology, made by Dr. Charles C. Abbott, Prof. N. S. Shaler, Prof. E. B. Andrews, and Lucien Carr, Assistant Curator; also, an elaborate paper, by Ad. F. Bandelier, "On the Art of War and Mode of Warfare of the Ancient Mexicans."

Dr. Abbott's report is specially interesting, as containing an account of his discoveries of rude stone implements in the drift-gravels of the Atlantic border in New Jersey. These implements were found at various depths, mingled with the gravels, near Trenton and along the banks of the Delaware. In the opinion of both Dr. Abbott and Prof. Shaler these gravels are of glacial origin, and the implements obtained were wrought by man, who inhabited the region at the close of the ice age, or during interglacial periods, where the climate favored their existence.

This is in striking accord with the previously-expressed views of Prof. Grote, who, in a paper read at the Detroit meeting of the American Association in 1875, and later in an address entitled "Early Man in North America," published in this Journal for March, 1877, takes the ground that man lived here during the glacial period. In this address, alluding to the implements discovered by Dr. Abbott, he says: "To me it seems clear that the men who used these rough tools dwelt on the edge of the glacier, and their implements have become buried in the moraines which were forming at many different points during the ice period."

The Relations of Pain to Weather. By S. Weir Mitchell, M. D. Pp. 25. Philadelphia.

Dr. Mitchell's reputation as an original investigator will secure for this paper careful attention. It was first published in the *American Journal of Medical Sciences* for April, 1877, being a study of a case of traumatic neuralgia, considered especially in its relations to atmospheric con-

ditions. This is probably the first attempt to study the subject in so thorough and systematic a manner as was done in the instance given. The observations extended through a period of three years, and fully justify the conclusion that neuralgic conditions have a close and very direct relation to atmospheric states or changes. Precisely what conditions of the atmosphere excite neuralgic pain is by no means determined. Dr. Mitchell says, "Either it is the combination (of conditions) which works the mischief, or else there is in times of storms some as yet unknown agency productive of evil."

A REVIEW OF THE BIRDS OF CONNECTICUT. By C. HART MERRIAM. New Haven: Tuttle, Morehouse & Taylor, 1877.

THIS catalogue of 165 pages is from No. 4 of the "Transactions of the Connecticut Academy," 1877, and is a valuable addition to the ornithology of New England. We are informed by it that 291 species of birds are found in the State. These are grouped in 47 families. Of these the scientific and common names are given, with copious notes on their habits and characteristics: 135 species are summer residents, 90 species are migratory only. The now familiar English sparrow is found in most parts of the State, and, so far as the author is aware, was first introduced into New England in the fall of 1858. At that time six birds were liberated in a large garden at Portland, Maine. The catalogue contains a list of works relating to New England ornithology, and is thoroughly indexed.

THE GLACIAL PERIOD IN THE SOUTHERN HEMISPHERE. By THOMAS BELT, F. G. S. London, 1877.

IN this pamphlet Mr. Belt presents many facts to show that extensive glaciation occurred in the Southern as well as in the Northern Hemisphere. It occurred in the southern part of Africa and of Australia, extensively in New Zealand and South America. His views in regard to elevation and subsidence of land in glacial times, and the development of ice, filling the beds of Northern and Southern oceans, so that the drainage of continents was arrested, the waters of rivers being "pounded back," probably will not be immediately accepted by practical geologists.

POISONOUS MUSHROOMS. By J. OTT, M. D. Pp. 5.

THE author's conclusions are that at least one species of mushrooms (*Agaricus muscarius*) contains a poisonous alkaloid, *muscarine*, which is probably the poisonous principle of all noxious mushrooms; and that, in cases of mushroom-poisoning, in addition to the usual treatment — emetics, stomach-pump, purgatives, and gallic acid —*atropine* should be administered subcutaneously.

MAP OF THE WHITE MOUNTAINS OF NEW HAMPSHIRE, FROM WALLING'S MAP OF THE STATE. Boston: Publication-Office of H. F. Walling, 1877.

THIS map is drawn to a scale of 2½ miles to an inch, and comprises the principal part of the White Mountain region. It gives in detail the routes, principal villages, streams, and elevations, which are indicated by color, and points of special interest accessible to tourists. The topographical features are well defined. As a pocket-guide for travelers the map is indispensable.

THE *Young Scientist* is a monthly magazine designed to interest young persons in scientific subjects, and to familiarize them with scientific experiments and habits of thought. But, while it addresses mainly a juvenile audience, the *Young Scientist* is not in the least puerile, and may be read with no little profit by older heads. We wish it success. New York: Published at 176 Broadway. Subscription, fifty cents per year.

PUBLICATIONS RECEIVED.

Compendious German-and-English Dictionary. By William Dwight Whitney. New York: Henry Holt & Co. Pp. 905. $3.50.

Pottery: How it is made. By G. W. Nichols. With Illustrations. New York: Putnams. Pp. 142. $1.25.

The Boy Engineers. By Rev. J. Lukin. Same publishers. Pp. 344. With Illustrations. $1.75.

Transmission; or, Variation of Character through the Mother. By G. B. Kirby. New York: S. R. Wells. Pp. 68. 25 cents.

Geographical Surveys west of the 100th Meridian. Vol. IV., Paleontology. Lieutenant G. W. Wheeler in charge. Washington: Government Printing-Office. Pp. 365 of Letter-press and numerous Lithographic Plates.

Transactions of the American Fish-Culturists' Association, 1876-'77. New York: J. M. Davis print. Pp. 131.

A Plea for Candor in Bible-Reading. By a Citizen of, Jackson. Jackson, Tenn.: J. G. Cisco. Pp. 44.

Wisconsin Geological Survey. Report for the Year 1877. By T. C. Chamberlain. Madison, Wis.: D. Atwood print. Pp. 93.

Variations of the Leaf-Scars of *Lepidodendron aculeatum*. Pp. 15. Also of Certain Sigillariæ. Pp. 5, with Plates. By H. L. Fairchild. From "Annals of the New York Academy of Sciences."

Transactions of the American Entomological Society. Vol. VI., Nos. 3 and 4. With Plates. Philadelphia: The Society. Pp. 174.

Twelfth Annual Report of the Sheffield Scientific School. New Haven: Tuttle, Morehouse & Taylor print. Pp. 53.

Discovery of Stone Implements in Glacial Drift, in North America. By T. Belt. From *Quarterly Journal of Science*. Pp. 22.

Willard's Method of treating Ores. Plymouth, Mass.: Avery & Doten print. Pp. 15.

Bulletin of the University of California, No. 28. Pp. 72.

Dental School of Harvard University. Cambridge: C. W. Lever print. Pp. 9.

Memorial to Congress for the Improvement of the Mississippi River. St. Louis: J. J. Daly & Co. print. Pp. 38.

Froward to the Froward. By E. A. Beaman. New York: E. H. Swinney. Pp. 28.

Methods of Arithmetical Instruction. By F. W. Bardwell. New York: Putnams. Pp. 34. 15 cents.

The Glycogenic Function of the Liver. By J. Le Conte. From *American Journal of Science*. Pp. 9.

Nature and Possibilities of Social Science. By P. Burton. Aurora, Ill.: *Herald* print. Pp. 8.

On a Branch Naval Observatory. By Rear-Admiral Rodgers. Pp. 6.

The Kirografer and Stenografer Monthly. $1 per year. Amherst, Mass.: J. B. & E. G. Smith.

Is the Universe governed by a Devil? By J. F. Smith. Oak Lawn, R. I.: Home Publishing Co. Pp. 14. 15 cents.

Contributions from the Chemical Laboratory of Harvard College. By J. P. Cooke, Jr. Pp. 132.

Hereditary Epilepsy. By Dr. E. Dupuy. On the Seat of the Vaso-Motor Centres. By the same. New York: Reprinted from the "Transactions of the American Neurological Association."

Researches into the Physiology of the Brain. By the same. New York: Putnams. Pp. 31.

POPULAR MISCELLANY.

Anticipations concerning the Phonograph.—Dr. William F. Channing, writing to the *Providence Journal* on Edison's phonograph, thus presents its future: "The sheet of tin-foil or other plastic material receiving the impressions of sound will be stereotyped or electrotyped so as to be multiplied and made durable. Or the cylinder will be made of a material plastic when used, and hardening afterward. Thin sheets of papier-maché, or of various substances which soften by heat, would be of this character. Having provided thus for the durability of the phonotype plate (a better name than phonograph), it will be very easy to make it separable from the cylinder producing it, and attachable to a corresponding cylinder anywhere or at any time. There will doubtless be a standard of diameter and pitch of screw for phonotype cylinders. Friends at a distance will then send to each other phonotype letters, which will talk at any time in the friend's voice when put upon the instrument. How startling, also, it will be to reproduce and hear at pleasure the voice of the dead! All of these things are to be common, every-day experiences within a few years. It will be possible, a generation hence, to take a file of phonotype letters, spoken at different ages by the same person, and hear the early prattle, the changing voice, the manly tones, and also the varying manner and moods of the speaker—so expressive of character—from childhood up!

"These are some of the private applications. For public uses, we shall have galleries where phonotype sheets will be preserved as photographs and books now are. The utterances of great speakers and singers will there be kept for a thousand years. In these galleries, spoken languages will be preserved from century to century with all the peculiarities of pronunciation, dialect, and brogue. As we go now to see the stereopticon, we shall go to public halls to hear these treasures of speech and song brought out and reproduced as loud as, or louder than, when first spoken or sung by the truly great ones of earth. The ease with which the phonotype cylinders may be stereotyped or electrotyped and multiplied, has been spoken of. Certainly, within a dozen years, some of the great singers will be induced to sing into the ear of the phonograph, and the electrotyped cylinders thus obtained will be put into the hand-organs of the streets, and we shall hear the actual voice of Christine Nilsson, of Miss Cary, or even of Jenny Lind and Alboni, ground out at every corner!

"In public exhibitions, also, we shall have reproductions of the sounds of Nature, and of noises familiar and unfamiliar. Nothing will be easier than to catch the sounds of the waves on the beach, the roar of Ni-

agara, the discords of the streets, the noises of animals, the puffing and rush of the railroad-train, the rolling of thunder, or even the tumult of a battle.

"Edison has recently stated that his best instrument will now talk so as to be heard at a distance of 175 feet. The conditions for increasing the sound are so simple that there can be no doubt of any desirable extension in this direction."

Garden-Schools.—The New York Academy of Sciences has twice had under consideration plans of using the public parks for scientific and hygienic purposes. One of these purposes was the propagation of febrifuge trees and plants; the other the use of part of these public grounds as garden-schools.

This latter project is to be commended for various reasons: As education becomes general, schoolhouses cannot contain all the scholars. The present school-crowding already necessarily generates or propagates among the pupils various epidemic and other diseases. The shutting of the children in class-rooms when the sun shines, and the air is bracing, is producing leucæmic affections. The eyesight is impaired by concentration on books; and the training of the mind to the exclusion of the exercise of the senses, and of the other active functions, isolates the child from the real world, and feeds him on abstractions which predispose to several forms of insanity.

On the other hand, open-air life, study, and exercise, invigorate all the tissues, organs, and functions of the body.

The plan of such garden-schools must vary, of course, for each locality. For the city of New York, as presented to the Academy of Sciences by Dr. E. Seguin, and by the Academy to the mayor, it would be somewhat as follows: A part of each of the small parks would be planted with specimens of ornamental, edible, medicinal, textile, and other plants, where groups of children could go with their teachers to breathe and learn.

In the Central Park large tracts would be devoted to indigenous and exotic plants, to zoölogy and ichthyology, mineralogy, and specimen sections of American geology, hydrology, etc. The public-school pupils would visit these places with their teachers; and, when the weather happened to be unfavorable, they could find shelter in the public libraries, museums of painting and natural history, which fringe the park, and where they could continue their studies of Nature.

In a word, the schoolhouse must be used only when it cannot be helped, the rules of physiological education needed by a free people, being: Never to teach in-doors what can be learned out-doors; never to explain in the abstract what can be demonstrated in the concrete; never to teach with books what can be perceived in objects; never to teach by images when Nature itself is at hand; never to show dead Nature when living Nature is obtainable; and never to require belief where seeing and understanding are possible. New York's beautiful Central Park might thus be made an educational establishment of the highest value. In the Kew Gardens at London, seventy-five acres are given up to the students, without at all impairing the beauty of the landscape. The same might be said of the Gardens of Acclimation of London, Paris, Algiers, Calcutta; of the Botanical Gardens of Montpellier, Brussels, Geneva, which are partly schools and partly pleasure-grounds. In this respect we are sadly behind. Once reminded that our parks have been created "equally for the enjoyment of the public, and for the education of the children," our public authorities, it is to be hoped, will realize the need of preserving them for their original purposes, and so improving them that they may every year become more and more indispensable to our citizens.

New Fossil Reptiles.—In addition to the remarkable Jurassic reptiles recently described by Prof. Marsh from the Rocky Mountains, several others are announced by him in the March number of the *American Journal of Science*. One of these, a gigantic Dinosaur (*Atlantosaurus immanis*), was much larger than any land-animal, recent or fossil, hitherto described. The femur of this monster was over eight feet (2,500 millimetres) in length, and the other remains preserved are equally huge. If this reptile had the proportions of a crocodile, it must have been over a hundred feet

long! It was certainly gigantic enough to entirely disprove the theory, generally accepted, that the elephant is as large as any animal can be that moves upon the land, for the bulk of this reptile must have been at least three times that of any known Proboscidian.

Among the other Dinosaurs described in this paper is *Morosaurus impar*, another herbivore belonging to the same family, and about twenty-five feet in length, and *Creosaurus atrox*, its carnivorous enemy, nearly as large, each representing a new genus. Two small species, belonging to the new genus *Laosaurus*, are also described. The large herbivorous Dinosaurs, from the American Jurassic, represent, according to Prof. Marsh, a well-marked family, the *Atlantosauridæ*, which have but three or four vertebræ in the sacrum, five well-developed digits in each foot, and the hind-feet ungulate and plantigrade—characters not before found in Dinosaurs.

Trees and Health.—Certain observations made by a correspondent of the *Chemical News* are deserving of the attention of sanitarians. According to him, the cantonment of Goruckpoor, in Northwest India, though situated near the forest and in the neighborhood of a large swamp, was thirty years ago considered a healthy station. A large grove of mango-trees existed between the swamp and the station. For some reason this grove was cut down, and *the station became unhealthy*. Again, the civil station of Futtehpoor is situated between Allahabad and Cawnpoor, in an arid plain, but near a pretty extensive marsh. This place was considered extremely unhealthy, until the magistrate planted *between the station and the swamp* a belt of quick-growning babool-trees. As the trees grew, the place became much less unhealthy. In these two cases the trees appear to have acted as a screen or filter, protecting the population from the effects of the malaria generated in the swamps. It may be added that it would be difficult to find trees more dissimilar in foliage than the mango and the babool. "Is it not probable," asks the author, "that where beneficial effects have followed the planting of the eucalyptus, the same may be due as much to the screen which the plantation has interposed, as to any peculiar action of, or exhalation from, the leaves or stem of the tree?" Referring to the changes produced, as regards salubrity, at the Trappist monastery of Tre Fontane, near Rome, which changes have been ascribed to the peculiar virtues of the eucalyptus, the author calls attention to the fact that the deep ploughing of the soil and the removal of seven hundred cart-loads of human bones from the precincts of the monastery may perhaps be credited with some share in producing the change. So, too, the eucalyptus-trees may have served, in this case also, as a screen.

Carnivorous Plants.—Mr. Francis Darwin, in a paper entitled "The Nutrition of *Drosera rotundifolia*," describes a series of experiments made by himself to determine whether or not insectivorous plants profit by their carnivorous habits. With this object two hundred plants of *Drosera rotundifolia* were transplanted (June 12, 1877) and cultivated in six soup-plates filled with moss during the rest of the summer. The area of each plate was equally divided by a low wooden partition, one side being destined for the plants to be fed with meat, the other for those to be starved. Access of insects was prevented by inclosing the plants in a gauze case. The method of feeding consisted in supplying each leaf (on the fed sides of the six plates) with one or two small bits of roast-meat, each weighing about one-fiftieth of a grain, every few days. On July 17th it was evident that the leaves on the "fed" side were of a distinctly brighter green, showing that the increased supply of nitrogen had allowed a more active formation of chlorophyll-grains to take place. From this time forward the "fed" sides of the plates were clearly distinguishable by their thriving appearance and their numerous tall and stout flower-stems. On August 7th the ratio between the number of "starved" and "fed" flower-stalks was 100 : 149.1. And on comparing the number of stems actually in flower, it was clear that the starved plants were losing the power of throwing up new flower-stems at an earlier date than their rivals. In the middle of August the leaves were counted in three plates, and were found to be one hundred and eighty-seven on the starved and two hundred and fifty-six on

the fed side. The seeds being ripe at the beginning of September, all the flower-stems were gathered, and the plants of three plates were picked out of the moss and carefully washed. The other three plates were left undisturbed: the relative number of plants which will appear in the spring on their "fed" and "starved" sides will be a means of estimating the relative quantities of reserve material stored up. Mr. Darwin gives in the following table the results of counting, measuring, and weighing, the various parts of the two sets of plants:

Ratio between the number of starved and fed plants	100 : 101.2[1]
Ratio between weights of the plants *exclusive* of flower-stems	100 : 121.5
Total number of flower-stems	100 : 164.9
Sum of the heights of the flower-stems	100 : 159.9
Total weight of flower-stems	100 : 231.9
Total number of capsules	100 : 194.4
Average number of seeds per capsule	100 : 122.7
Average weight per seed	100 : 157.3
Total calculated *number* of seeds produced	100 : 241.5
Total calculated *weight* of seeds produced	100 : 379.7

New Process of Sugar-Manufacture.—Mention is made in the *Revue Scientifique* of a new process for sugar-manufacture, invented by Prof. Loewig, of Breslau, which greatly simplifies the work. Instead of using lime to defecate the liquor, then having recourse to a double carbonization by carbonic acid, with a view to eliminate this lime in the shape of lime carbonate, and lastly filtering the carbonated liquor through animal charcoal—processes which allow about one-third of the beet-sugar to be transformed into molasses.—Loewig simply adds to the crude liquor hydrate of alumina which he has discovered the means of preparing on the large scale. This hydrate of alumina retains the coloring albuminoid and nitrogenized matters, forming with them a black scum which is removed. All that remains to be done is to concentrate the almost absolutely pure sugary liquid which remains. If this process proves successful, it will revolutionize the sugar-manufacture.

Intensity of Different Colored Lights.—Prof. O. M. Rood describes, in the *American Journal of Science*, a simple method devised by him for comparing the intensities of light of different colors—a problem that has long been considered one of the most difficult in photometry. To measure the luminosity of *vermilion*, for example, he attaches a circular disk of vermilion cardboard to the axis of a rotation apparatus, a smaller circular disk of black-and-white cardboard being simultaneously fastened in the same axis, so that by varying the relative proportions of the latter a series of grays might be produced at will. First the compound black-and-white disk is so arranged that, on rotating the machine, a gray *decidedly darker* than the vermilion is produced. Then the gray is gradually lightened, till the observer becomes doubtful as to which is the more luminous, the gray or the vermilion; the angle occupied by the white sector is then measured. Next, a decidedly *more luminous* gray is compared with the vermilion, and its luminosity gradually diminished till again there is doubt as to which of the two, the gray or the vermilion, is the more luminous; and then, again, the white sector is measured. The mean of ten such experiments showed that when the luminosity of both disks was the same, the white sector of the black-and-white disk was 23.8 of its whole area, and hence that the luminosity of the vermilion cardboard was in the same ratio, namely, 23.8 per cent. to white. Proper allowance was made by Prof. Rood for the amount of white light reflected by the black disk. The relative luminosity of other colors may, of course, be ascertained in the same way.

Causes of the Chinese Famine.—According to a correspondent of the London *Spectator*, Frederick H. Barbour, the famine now prevailing in the northern provinces of China began in the fall of 1875. Its immediate cause was the long absence of rain, but the phenomenon to which it was and still is primarily due is the gradual desiccation of the vast plains of Chi-li and Shang-Tung, a process which, commencing in the table-lands of Central Asia, has now reached the densely-peopled northern provinces of China. Mr. Barbour has for the last two years been in constant communication with the famine-stricken districts, and the letters

[1] In all cases "starved"=100.

he receives convey appalling intelligence. "Fancy," says he, "a tract of country larger than thirteen Switzerlands a prey to want that it is wellnigh impossible to relieve. The people's faces are black with hunger; they are dying by thousands upon thousands. Women and girls and boys are openly offered for sale; when I left the country, a respectable married woman could be easily bought for six dollars, and a little girl for two. In cases where it was found impossible to dispose of their children, parents have been known to kill them, sooner than witness their prolonged sufferings, in many instances throwing themselves afterward down wells, or committing suicide by arsenic. . . . The population subsisted for a long time on roots and grass; then they found some nourishment in willow-buds, and finally *ate the thatches off their cottages.* The bark of trees served them for several months, and last July I received specimens of the stuff the unhappy creatures had been by that time reduced to. The most harmless kind was potato-stalks, tough, stringy fibres, which only the strongest teeth could reduce to pulp. The other description was *red slate-stone.*"

Proportion of Theine in Different Kinds of Tea.—It was some time ago asserted by Claus, as the result of his analyses of different grades of tea, that the lower the grade of tea the higher is the proportion of the alkaloid theine it contained. Thus, according to this author, the brick-tea used in Mongolia and Siberia, which is made up of all sorts of refuse, as dead leaves, stalks, and the like, contains far more theine (about 3.5 per cent.) than the higher qualities (in which the proportion found by him was from 1 to 1.3 per cent. only). Very different results have now been obtained by another chemist—Markovnikoff, of Moscow. Having made a series of analyses of one kind of tea by the various analytical methods hitherto in use, he is able to point out the deficiency of these methods. For instance, ether extracts only one-third of the whole amount of theine in a sample of tea, and benzole only one-quarter. Using, therefore, a more perfect method, and analyzing six kinds of tea—some of the very highest, others of the very lowest grades—he arrives at the result that the amount of theine in these varies very little—from 2.08 to 2.44—and that it increases regularly, with one exception, with the quality of the tea; while the amount of ash given by each kind regularly decreases from 6.1 to 5.7 per cent. from the highest to the lowest grade. These differences, however, being very small, Markovnikoff supposes that the quality of tea depends, not at all or only a very little, upon the amount of theine, and far more on the quantity of tannic acid and aromatic oils it contains; but that, on the whole, teas made from younger leaves contain more theine than those from older leaves.

Do Lightning-Rods attract?—The old dogma that a lightning-rod no more attracts electricity than an umbrella attracts rain, is not strictly exact—for, while the umbrella has no influence on the course of the descending rain-drops, it is certain that the presence of a conductor very materially changes the earthward course of the electric fluid. The Vice-President of the British Meteorological Society, Dr. R. J. Mann, in a letter to the London *Times*, states as follows the *rationale* of the action of lightning-rods in protecting buildings:

"A conductor in the near presence of a charged thunder-cloud becomes inductively excited, a very strong charge of the opposite kind of electricity to that in the cloud being drawn to the top of the rod. When this state of things has been brought about, there certainly is a stronger tendency for a spark or flash to pass across the intervening air-gap than there would be in the absence of any such inductive disturbance. The electricians who still hold this view [namely, that the lightning-rod's attraction is equal to the 'attraction' of an umbrella] would, nevertheless, hesitate to carry their argument home to its ultimate conclusion by saying that there is no attraction between the outer and the inner coating of a Leyden-jar immediately before the electric forces shatter the glass to effect the discharge of the jar. It is indeed almost universally held that the charge of a Leyden-jar is chiefly due to the attraction of the severed electric forces exerting themselves to unite through the insulating barrier of the glass. The charge in the outer coating of the jar comes up from the earth under what, in familiar terms, can hardly be called anything else but the 'attraction' of the inner charge."

Cooking.—Nothing, probably, has more direct influence over our physical and moral well-being than the preparation of the food

we eat, and it is not too much to suppose that a proper knowledge of the culinary art would, if tolerably wide-spread, do not a little to diminish crime and drunkenness. Now that ladies are to be admitted without let or hinderance to all the degrees of the University of London, we hope the Senate will see fit to add "cooking" to the list of subjects for the B. Sc. Science in the kitchen has long been a desideratum, and cooking has not hitherto been regarded really as a branch of chemistry, and, as such, an ennobling occupation. The English of all classes have everything to learn on this subject, and even the very best of our cooks seem to go right rather by intuitive talent than by any exact knowledge which they may possess. In the cookery-book of the future, however, we may hope to see milligrammes, cubic centimetres, and degrees of Celsius, replace the less exact measurements to which cooks have been accustomed, and then, perhaps, success in cooking will become a certainty.—*London Lancet.*

Distribution of Color in Animals.—It is not in the least unusual to observe in domesticated mammals asymmetrical distribution of color, while in feral animals the distribution is always symmetrical. A number of facts illustrating this are cited by Mr. J. A. Ryder in the "Proceedings" of the Academy of Natural Sciences of Philadelphia. He instances the case of a raccoon in the collection of the Philadelphia Zoological Society, in which the variation from the typical coloration of the species was great. Here the color areas were disposed symmetrically in the same manner as in the ordinary specimens. The difference was only in the shade, this specimen being of a rich, brownish yellow, except the tail-rings and the lateral bands on the face, which were of a considerably deeper hue. The nose, feet, and eyes, in the ordinary specimens, are black, while in this specimen all the dermal structures were of a much lighter tint. Again, in a specimen of *Lepus silvaticus*, in the Academy's collection, the fur is cream-colored, and very long and soft, but perfectly symmetrical and uniform in color. In rats, nearly white, the color areas were also found to be very nearly the same on both sides. The same is to be said of specimens of Virginia deer. In many domestic animals there is a decided tendency to preserve the symmetry of the ancestral type, but domestication seems to be at the bottom of the variability and asymmetry of color of animals brought under its influence. In conclusion, the author summed up the facts as follows: 1. Bilateral symmetry of coloration is interfered with in some way by domestication; 2. Where variation of color takes place in feral animals, they are invariably, so far as observed, symmetrically colored; 3. It is possible that the degree of asymmetry is an indication of the length of time that domestication has been operative.

Travels in Formosa.—In the island of Formosa the inhabitants of all the level country are Chinese. Wages on the island are 20 per cent. higher than in Amoy. Opium makes up two-thirds of the value of all their foreign imports. Opium-smoking prevails to an extraordinary extent; but a traveler in the island, Mr. James Morrison, affirms that there is not much excess of indulgence in that habit. The coolies that carried his palanquin always smoked opium at night, and continued smoking after he had gone to bed; yet they were always ready to start before six o'clock in the morning, and seemed fresh. A coolie will carry twenty miles a day for ten consecutive days. Smoking in this way costs from ten to fifteen cents a day. The daily wage of a chair-coolie is seventy-five cents. The chair is the usual vehicle for travel in Formosa. Ponies may be used for riding short distances, but the numerous rivers, too deep to ford, and too rapid to swim, render them useless for long journeys. The Formosan chair is very light, but hardly roomy enough for the average man of European race. It is forty inches long, forty-eight inches high in the centre, and forty inches at the sides, twenty-one inches wide inside, with a seat about ten inches high. The method of carrying, says Mr. Morrison, is simply diabolical. Four men carry, two being placed at the ends of the poles, and two close to the chair, one in front and one behind, the two latter supporting the chair by means of cross-pieces or yokes pass-

ing over the shoulders and attached to the poles by ropes. These ropes are so adjusted that when the men stand still, and the chair is loaded, the poles are bent about three inches. In carrying, the easy swing of the ordinary chair is lost, for, just as the Formosan chair is coming down gently, it is brought up short by the men close to it. The motion is exactly the same as is used for jigging crushed metallic ores.

Chinese Medicines.—The Chinese pharmacopœia contains instructions for preparing sundry very curious medicines, as, for instance, various animal "wines"—mutton-wine, dog-wine, deer-wine, tiger-bone wine, snake-wine, tortoise-wine, and so on. These "wines" (*chiu*) are employed instead of alcohol as a solvent for articles used as medicines. The mode of preparing mutton-wine is described as follows by Dr. D. J. Macgowan, of Shanghai: The ingredients are one sheep, forty catties (a catty equals 1⅓ pound) of cow's-milk wine, a pint of sour skimmed milk, eight ounces brown sugar, four ounces honey, four ounces fruit of dinocarpus, one catty raisins, and about one catty of half a dozen other drugs. The utensils employed are a large cast-iron pot, a wooden barrel (*boorher*) about two feet high, and tapering, open at both ends, a smaller iron pot, an earthenware jar; felt belts and cow-dung are used for making the apparatus air-tight. The boorher is set on the large pot, the joining being first calked with paper, and then daubed on the outside with cow-dung and ashes; the boorher, too, is made air-tight in the same way. Then pour in the wine, add half the raisins, cut or crushed, half the sugar, the milk, and the bones of the sheep's legs, from the knees down, after breaking them open. From the other bones strip all the fat and most of the flesh, and hang them inside the boorher beyond the reach of the wine. Put in the medicines, the honey, and the remainder of the sugar and raisins. The earthenware jar is then suspended in the centre of the boorher, and the smaller iron pot is set on top, the joint being made air-tight by paper, cloth, and felt bands. A fire is now made under the great pot; when the upper pot feels warm to the touch, fill it with cold water. When this water is too hot to touch, it is ladled out, and the pot filled again with cold water. When this in turn becomes hot, the fire is slackened, the upper pot taken off, and the earthenware pot, which is now found to be full of a dirty-brown liquor, is taken out, the liquid poured off, the vessel replaced, and the upper pot, filled with cold water, again set upon the top of the boorher. When the water on top is again heated, the whole operation is completed. The earthenware pot is now again found to be about half full, and its contents are poured off, allowed to cool, and put up in jars.

Utilization of Blast-Furnace Slag.—Within a few years great progress has been made in the utilization of blast-furnace slag, and that material is now applied in many ways with great advantage. Thus, slag "sand" is employed for making concrete, building-bricks, mortar, and cement; slag "shingle" for concrete, also for roadways; slag "wool" for covering steam-boilers and pipes, ice-houses, etc., also for filtering-purposes; blocks of slag-concrete are used for paving, for curbstones and the like; finally, by Britten's process, slag is used in the manufacture of glass for roofing, and for other purposes not requiring pure glass. In making building-bricks of slag, the slag-sand is mixed with selenitic lime, with the addition of iron oxide, and pressed in moulds. The cement is made from the slag-sand, common lime, and iron oxides. It is little inferior to Portland cement in strength, while it does not cost one-fourth as much. The concrete made from this cement, mixed with the "shingle," is an excellent conglomerate for use in monolithic structures. It is stated by Mr. Charles Wood, in a paper read before the British Iron and Steel Institute, that "it took two good men, with steel bars and sledge-hammers, as much as four days to cut through a wall of this concrete about twenty-six inches thick." Mr. Wood exhibited to the Institute bottles of slag-glass, also specimens of slag-wool. The latter product, according to Mr. Wood, is obtained as follows: A jet of steam is made to strike a stream of molten slag as it falls into the slag-bogies or wagons. This jet scatters the molten slag into shot, and as each shot leaves the stream it carries a fine

thread or tail; the shot drops to the ground, but the fine woolly fibre is sucked into a large tube, and discharged into a chamber. This chamber is very large, and is covered with fine wire netting. The steam and air carry the woolly particles all over the chamber—the finest into recesses formed for the purpose, the heavier into the body of the chamber. The wool is of a snowy-white appearance.

The Mechanics of Nature.—The Rev. J. G. Wood, author of several popular works on zoölogy, has lately published a volume entitled "Nature's Teachings," which is intended to show that nearly every one of man's mechanical inventions has been anticipated by Nature. From a notice of the work in an English journal we copy a few instances of human inventions that have their prototypes in the animal world. Alluding to the principle on which the life-boat is formed, Mr. Wood observes that "the eggs of the gnat, which adhere together by a glutinous coating, are arranged side by side so as to form the figure of a boat; that the lines of the best life-boats are almost identical with those of the gnat-boat; and that both possess the power of righting themselves if capsized." Mr. Wood observes the principle of the screw in a fish's tail; finds a remarkable resemblance in the iron mast to the quill of the porcupine; and explains how the improvement in the construction of iron ships caused by making the outer shell double and dividing it into separate compartments is exemplified in the skull of the elephant. Many of the author's nautical illustrations are curious, and among others he points out that the Boyton life-dress is simply a modification of the *Physalis*, "which floats on the surface of the ocean like a bubble." The weapons used in war have also their prototypes in the works of Nature. In a chapter on projectile weapons Mr. Wood notices the archer-fish, which gains its livelihood by shooting drops of water at flies, and reminds us that the same principle was employed, though unsuccessfully, on the so-called pneumatic railway at Croydon. From the archer-fish we may pass appropriately to the angler-fish, a creature with an enormous mouth and small body. On the top of its head are some bones set like a ring and staple, and, at the end of these bones, long fleshy appendages, which, on being waved about, look as if they were alive. "The fish darts at the supposed morsel, and is at once ingulfed in the huge jaws of the angler-fish, which, but for this remarkable apparatus, would be scarcely able to support existence, as it is but a sluggish swimmer, and yet needs a large supply of food." There are different modes of catching fish, and the capture by rod and line is curiously anticipated by the worm known to naturalists as *Nemertes Borlasii*, which can extend itself, some say, to ninety feet, and looks, as Kingsley has said, a mere knotted lump, small enough to be put in a dessert-spoon. The little fish that chances to touch this "slimy tape of living caoutchouc" has no chance of escape, for he is being "'played' with such a fishing-line as the skill of a Wilson or a Stoddart never could invent." The principle of the baited trap is illustrated by carnivorous plants like the Venus's flytrap of the Carolinas, and the *Drosera* or sundew of England, and the principle of the spring-trap by the jaws of the dolphin. Defensive armor in its several varieties is strikingly illustrated by the protection afforded in many instances by Nature, and Mr. Wood's treatment of this branch of his subject will be found of great interest.

How Ants stand Heat and Cold.—The ability of ants to survive exposure to great cold or great heat, and submersion in water, is shown in a very interesting note by the Rev. H. C. McCook, published in the "Proceedings of the Academy of Natural Sciences" of Philadelphia. In one instance, a few ants, of the species *Formica Pennsylvanica* (the Pennsylvania carpenter-ant) dropped out of their nest and fell upon ice, in the depth of winter. Forty-eight hours later they were alive, being imbedded in the ice within the small depressions made by their animal heat. They moved about on being taken from the ice, and became quite active when placed in the closed hand. The power of resisting great heat is illustrated by Mr. McCook's own observations, as also by a quotation from manuscript notes on the "Ants of Texas," written by the late Dr. Lincecum. A community of that highly-inter-

esting species, the "agricultural ant" (*Myrmica molefaciens*), was located near a blacksmith-shop, which had been in operation five years. During all that period the smiths had built their fires for heating wagon-tires on the pavement or flat mound of these ants. This occurred, on an average, as often as two or three times a week. Frequently, as many as nine tires a day had been heated upon the mound. After five years of such experience, Dr. Lincecum records that he saw numbers of ants at work clearing out the entrance to their city before the fire, that had just been used for heating tires, was entirely extinguished. They seemed to have learned all about fire, and knew how to work around and among the half-extinguished coals without injury. In illustration of the third point Mr. McCook writes as follows:

"Last summer (1876) I discovered a formicary of mason-ants, apparently a variety of *F. rufa*, the fallow-ant. I placed these ants in an artificial formicarium, which was insulated in a tub of water. One night the covering by which the formicarium was protected during bad weather was left off, or removed by some meddler. A heavy shower fell early in the evening. In the morning the formicary was flooded; the ants were dead—dead and lying under five inches of water, mixed up with the mortar, which the rain had formed with the soil that composed the galleries. I poured out the water, and set the box in the sun with a forlorn hope that some of the ants might revive. At noon I chanced to open a paper box in which I had placed a dead female ant of the genus *Myrmica*. It had fallen into the tub, where it had been floating for many hours, apparently drowned. It was now crawling about the box alive. Thereupon I visited my dead fallow-ants, and found three of them moving about in the slush, endeavoring to extricate themselves. Another was struggling out of the muddy sediment in the jar which formed the lower part of the formicary. In short, the greater part of the drowned ants proved themselves to be veritable Noachians, and survived the flood."

Poisonous Leguminous Plants.—Dr. Rothrock, of the Academy of Natural Sciences of Philadelphia, calls attention to the fact that certain leguminous plants existing in our Southwestern Territories possess poisonous properties. In the vicinity of Fort Gartland, in Southern Colorado, cattle have repeatedly manifested symptoms of poisoning, the cause of which has been found to be the plant *Oxytropis lamberti*. The effects of eating this plant appear to be long enduring, the animal becoming demented, and wasting away, as its fondness for the poison increases to something like the opium-habit in man. Dr. Rothrock found at New Camp Grant, Arizona, another plant (*Hosackia purshiana*) whose effects are similar. From *Sophora speciosa*, another poisonous leguminous plant from Texas, Prof. H. C. Wood, Jr., has obtained an alkaloid which he names *Sophoria*, from the bean; its effects are not unlike those of the Calabar-bean. The Indians of Texas use the Sophora-bean to induce an intoxication, which lasts from two to three days. Half a bean will, it is said, cause intoxication, and a whole one may be productive of dangerous symptoms.

The Value of Scientific Weather-Observations.—Three daily observations of weather-phenomena are made at eighty-three stations of the Central Pacific and Southern Pacific Railroads and their branches, the area covered by the observations extending through eight degrees of latitude and twelve degrees of longitude. New observing-stations are set up in proportion as a new line of road advances. The records of these stations form the basis of a singularly interesting and important paper by Mr. B. B. Redding, which was read at a meeting of the California Academy of Sciences on January 21st. In illustration of the *financial value* of systematic observations of this kind, the author gives two cases where even superficial study of the meteorological records would have demonstrated in advance the inevitable failure of certain enterprises. For instance, in 1869 a large sum of money was expended in covering over some lakes near Summit Station with sheds, under which to cut ice for the San Francisco market. No sheds of sufficient width could be built that could bear the weight of snow falling at that point, and consequently the undertaking ended in disastrous failure. The meteorological records of the railroad companies show that the average rainfall at this point is *over five feet!* "Nearly all of this falls in the form of snow, and is equal, if the snow that falls did not become compact or melt, to a bank of snow each winter of sixty feet in depth!" A similar instance of the value of these records is fur-

nished by the experience of the farmers settled on the west side of the San Joaquin River. For years they have tried in vain to raise crops without artificial irrigation. That section of the State of California is an exemplification of the law thus expressed by Guyot, that "when a mountain-chain opposes an horizontal wind the air is forced up along the slopes, its vapors are condensed, and water the side exposed to the wind, while on the opposite slope the same wind descends into the valley dry and cloudless." The author considers very fully the operation of the chief laws of meteorology as applied to California in general, and to special localities in particular. Among the subjects discussed by him, we would mention the conflict between polar and equatorial winds; the influences of the Gulf of California; the comparative rainlessness of the Colorado and Mohave Deserts and the Tulare Valley; the rainfall in the great valleys and on the mountain-sides; the influence of the great deserts on temperature and rainfall; why the summer temperature of San Francisco is so low as it is, the mean temperature of summer at the Golden Gate being only 56°.

Purification of Illuminating Gas. — The method in common use for separating from coal-gas foreign suspended matter is founded on the principle of condensation by reduction of temperature on contact with water-cooled surfaces, or with water itself. But the liquid globules held in suspension in the gas may be condensed by causing a jet of gas to impinge upon any resisting surface, as a leaf of paper, or a plate of metal, and an apparatus for purifying gas according to this method has been constructed by Messrs. Pelouze & Audouin. The condenser of this apparatus consists mainly of an outer casing with a gas inlet at the lower part, and an outlet at the upper. Suspended within the casing is an annular water-tank, in which is balanced a miniature gas-holder, or bell, formed with four circumference-plates, two of which are perforated in rows with small holes, and two with large holes, the latter being opposite the blank spaces between the rows of the former. The gas from the inlet passes through the central space within the annular tank, and through the four perforated plates of the bell; the tar, etc., which condense on the non-perforated portions of the surface trickle down the plates into the water-tank. It has been found that if the perforated bell has a capacity of 35,317 cubic feet, it will suffice for works producing 3,531,700 cubic feet per twenty-four hours, or in the proportion of 1 to 100,000.

Properties and Production of Honey. — There was lately held in New York a convention of bee-masters from all parts of the United States, for the purpose of advancing the interests of the important industry with which they are identified. Among the papers read at this convention was one by Mr. F. B. Thurber, in which the commercial history of honey was given with considerable detail. The use of honey antedates that of sugar, going back many centuries before the Christian era, while the general use of sugar is of comparatively recent date. There are evidences of the high antiquity of sugar in China and India, but it appears to have been only vaguely known to the Greeks and Romans. The art of refining sugar was discovered by the Venetians in the sixteenth century. It is hard to say why the production of honey should have fallen so far behind the production of sugar. It is in the highest degree healthful and palatable, and its sources are as plentiful and as sure as those of sugar. In America, within the last few years, a wonderful advance has been made in the production of honey, as regards both quality and quantity.

Honey differs greatly in color and consistence. In the recent state it is fluid, but on being kept it is apt to form a crystalline deposit, and to be converted into a soft, granular mass; its color varies, being sometimes white, but usually yellowish, and occasionally of a brown or reddish tinge. When the bees are very young the honey undergoes less change, and remains nearly white: in this state it is called virgin honey. Ordinary honey is obtained both by pressure and by heat. Recently, however, a process has been invented by which honey is forced from the cells of the comb by centrifugal force, and the combs are then restored to the hives, to be again used by the bees for storing their honey. When honey is extracted from poisonous plants, it partakes

of their noxious properties. An instance of this recently befell a newspaper correspondent in Armenia. Having drunk some honey-sweetened water he was shortly afterward seized with headache, vomiting, coldness of the extremities, and temporary blindness, followed by a cataleptic state. Inquiry showed that the honey had come from the Botum Valley, where hemlock and henbane grow abundantly. Mr. Thurber points out the singular coincidence that more than 2,000 years ago Xenophon's soldiers met with a similar accident in the same locality.

Beavers in Colorado.—Mr. E. A. Barber, connected with Prof. Hayden's survey of the Territories, in the year 1874 had an opportunity of examining, on the banks of the Grand River, in Northwestern Colorado, the work of a colony of beavers. His observations, as published in the *American Naturalist*, are highly interesting, and we present the substance of them to our readers. He was first apprised of the vicinity of the beavers by watching a timber-shoot or clearing scooped out from a willow-brake to the water. Through this slide Mr. Barber passed into a grove of slender willows forming a thicket. About fifty feet from the river was a circular clearing where the animals had been at work; here the trees were larger, and many of them had been cut off obliquely within six inches of the ground—the logs had been hauled away. Farther on larger trees had been felled, which were still lying there, most of them measuring six and eight inches diameter, and one at least fourteen inches. The wood had been gnawed around the circumference, a few inches from the base, the deepest cutting having been done on the side next the water, so that the tree might fall in that direction. "I noticed," writes Mr. Barber, "that, wherever there were trees which had been felled some time past and fallen in the wrong direction, the newer work had been accomplished, without exception, in a systematic manner, all of the logs being cut so as to fall toward the dam. As I passed along the bank of the stream, I observed about ten timber-shoots running parallel at right angles to the course of the current, and separated by about fifteen feet. The larger trees had been cut near the water and above the dam for the purpose of floating them down, to save the labor of dragging from the interior. . . . I picked up several chunks of wood, six or eight inches in diameter and about as much in length, the ends being obliquely parallel; these had probably been prepared to fill up chinks in the walls of the dam. The trees had been, for the most part, cut into sections averaging ten feet in length, and the branches and twigs had been trimmed off as cleanly as a wood-chopper could have done them. Along the banks of the White River, some weeks before, I noticed several artificial canals which had been dug out in the absence of natural side-channels in the river. These were designed for floating down logs. One canal was four feet in width, seven in length, and several feet deep."

How the Spiders spin.—Happening to be in the fields during a sunshiny day in autumn, while a gentle wind was blowing, the Rev. H. C. McCook, of the Philadelphia Academy of Natural Sciences, took occasion to observe the aëronautic flights of the young spiders, whose silken filaments were floating from every stalk of grass. He found that many of the young arachnids—mostly of the family *Lycosidæ*, which are ground-spiders—selected the tops of the fence-posts as their starting-point. Having reached this "point of vantage," the spider always turned the face toward the wind. Then the abdomen was elevated to an angle of about 45°, and at the same time the eight legs were stiffened, thus pushing the body upward. From the spinnerets at the apex of the abdomen a single thread was ejected and rapidly drawn out by the breeze, often to the length of five or even six feet. Gradually the legs were inclined in the direction of the breeze, and the joints straightened out. The foremost pair of legs sank almost to the level of the post. Suddenly the eight claws were released and the spider mounted with a bound into the air, and was quickly carried out of view. The author distinctly noticed that at the instant of beginning its aërial journey, the spider would make an upward spring. He was also so fortunate as to be able to follow the flight of a spider for a distance of about eighty feet, and observed that the position of the

body was soon reversed, that is, with the head turned in the direction toward which the wind was blowing. Thus the long thread which streamed out above the aëronaut inclined forward, and at the top was in advance of its head. It was also observed that the legs were spread out, and that they had been united at the feet by delicate filaments of silk; this gave to the body increased buoyancy, owing to the increased surface thus offered to the resistance of the air. Before, or rather during its descent to the earth, a small white ball of silk was seen accumulated at the mouth of the spider, which, with the peculiar movements of the forefeet, palps, and mandibles, suggested the drawing in of a thread. The spider was, so to speak, *taking in sail.* Exactly the same effect was thus produced by the spider aëronaut, and by a strikingly analogous mode, as the human aëronaut accomplishes when he contracts the surface of his balloon by causing the inflating gas to escape.

NOTES.

MANY of the ills and diseases prevalent among women in our day are, no doubt, traceable to the sedentary mode of life so common among them. The progress of modern industrial art has done away with much of the household drudgery to which women were formerly subjected, and the result is in too many cases want of sufficient occupation for needed bodily exercise. The fruits of this state of things are strikingly exhibited in certain observations made by the late Mr. Robertson, a Manchester surgeon, who in his practice as a specialist for women's diseases found that in women who themselves performed all their household work there was no trace of certain complaints; that these complaints begin to make their appearance in women with one servant, become more pronounced in women who have two servants, or worse still with those who have three servants, and so on. He showed statistically that the deaths from childbirth were four times greater in the case of women with four servants than those with none.

No doubt the most voluminous compilation in any language is the "Illustrated Imperial Collection of Ancient and Modern Literature," published by the Chinese Government early in the eighteenth century. It comprises about 6,000 volumes. A copy of the work is on sale in Peking, and the British Museum has entered into negotiations for its purchase.

DURING the year 1876, in India, 48,000 cattle were destroyed by wild animals and venomous snakes; 22,357 wild animals and 270,185 poisonous snakes were killed at a cost of 120,015 rupees for bounties. In 1877, 19,273 persons were killed, and 54,830 cattle were destroyed.

REGULAR professorships of hygiene are to be established in the universities of Holland. The Faculty of the University of Utrecht has unanimously chosen Dr. Ludwig Hirt, of Breslau, to fill the new chair in that university.

THE Parkes Museum of Hygiene at University College, London, is approaching completion. The council of the college have devoted an area of 3,500 feet for the use of the museum, which is divided into a library and eight classes.

THE thickness of the coal-measures of Missouri is, according to Prof. Broadhead, in the *Western Review of Science*, for the upper measures, 1,300 feet; for the middle measures, 323 feet; and for the lower measures, 290 feet.

WHILE collecting corals on the reefs of Florida Mr. Pourtalès often felt the urticating effects of contact of the hands with millepora. It occurred to him to try the effect of applying a fresh piece of millepora to the tongue, when "instantly," he writes, "a most severe pain shot not only through that organ, but also through the jaws and teeth. The whole course of the dental nerves and their ramifications into every single tooth could be distinctly and painfully felt." The pain remained severe for about half an hour, but the sensation was perceptible for five or six hours.

THE President of the American Association for the Cure of Inebriates in his anniversary address quotes Dr. Magnus Huss as authority for the statement that in Sweden 1,500,000 persons—about one-half the population—annually consume 140 to 170 pints of spirits each. By their indulgence in strong drink the Swedes have deteriorated in stature and physical strength; new diseases have appeared, and old ones have increased fearfully.

A SUMMER school of zoölogy will next summer be stationed either on one of the Bahama Islands or at some point on our Southern coast, for the benefit of students of Union College, Schenectady.

THE Dean of Carlisle, Dr. Close, having made a violent attack on the practice of vivisection, denouncing it as a crime in the sight of that God "who careth for the sparrows," the *Lancet* very wittily retorts by quoting another Scriptural passage which the anti-vivisectionists are too prone to overlook: "Men are of more value than many sparrows."

EXPERIMENTS made by Astasheffsky go to prove that the saliva of the rat possesses very strong diastatic activity — in other words, very rapidly converts starch into glucose; and that, as a general rule, the saliva of the rodents holds the foremost place as regards the mammalia; next comes that of the carnivora; and lastly that of the herbivora—the latter being decidedly the weakest of the three.

A WRITER in the *School Journal* would have all school chairs or seats on their front edge not more than one-quarter the height of the occupant, or of such a height that when sitting well back the heels of the sitter may touch the floor at a distance in front of the seat equal to the height of the seat. This it is claimed allows the point of support to be changed for the sake of comfort, and yet allows no unhealthy pressure. The width of the seat should equal its height; the slant should be about three-quarters of an inch to the foot; the surface should be flat. The back should be not less than one-tenth in excess of the height of the seat, so as to give full support to the shoulder-blades; it should slant about two and a half inches to the foot. The desk at the edge next the sitter should be five-thirds the height of the highest edge of the seat; its slant should be about one inch to the foot; its lower edge should stand directly above the front edge of the seat.

THE cremation of the dead on battle-fields is strongly advocated by Mr. William Eassie in an address to a sanitary congress in England. He is confident that by means of portable crematories he could reduce to ashes 10,000 bodies in as many minutes of time. Interment of bodies by thousands must of necessity pollute the springs and contaminate the air.

THE building recently opened and dedicated in New York City for the use of the American Museum of Natural History consists of three stories, besides the basement and attic. These three stories constitute three halls, each 60 feet wide and 170 feet long, access being had by stairways in a tower at one end. The present building forms only a small part of a vast structure which it is designed to erect. The ground-plan of the future Museum may be described as a cross inclosed within a square. The portion of the structure now completed will form the northern end of the cross. The ground to be covered and inclosed by the buildings will be 850 feet in length by 650 feet in width.

A ROOF of zinc-coated sheet-iron, says the *Polytechnic Review*, does not wear out from oxidation, and does not crumble as does sheet-tin from the repeated contraction and expansion produced by changes of temperature. In Vienna and in Prague the manufacture of this roofing material is a growing industry.

THE year 1877 showed a very considerable increase in the production of cocoon-silk in France over the preceding year, viz.: in 1876 the product was 2,396,000 kilogrammes, but last year it was 6,783,000 kilogrammes. But this industry has yet to struggle hard if it is to attain in France its former condition, when the annual yield of cocoons was over 25,000,000 kilogrammes.

THE leather covers of books in public libraries suffer very much from the action of the combustion-products of coal-gas. According to Prof. A. H. Church, vellum appears to be unaffected by this cause; but calf is much injured, and russia still more so. Most damage is done to the books in the upper shelves of a library, where the heated products of combustion are mostly condensed and absorbed. The sulphur of the gas is the principal cause of its destructive influence. Analysis of watery extract of leather injured by this cause showed that sulphuric acid, free and combined, was present in the proportion of 8.42 per cent.

THE truth of the germ-theory of disease would seem to be demonstrated, at least with regard to one disease—splenic fever—by the researches of Dr. Koch. In cases of this disease, there accumulates in the blood and tissues, but especially in the spleen, a peculiar kind of bacteria—*Bacillus anthracis*. On inoculating animals with fluid containing either the bacilli themselves or their spores, Dr. Koch produced all the phenomena of splenic fever.

AN Italian chemist, Paesi, proposes to substitute, for the tannin-bath in the manufacture of leather, a solution, in water, of perchloride of iron and common salt. Hides may be tanned, according to this process, in from four to six months. Moreover, the perchloride of iron, being a powerful disinfectant, does away with many objectionable features of the tanning business as hitherto conducted.

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